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An Evaluation of Herbage and Browse Production Estimators Used in the 1980 RPA Assessment

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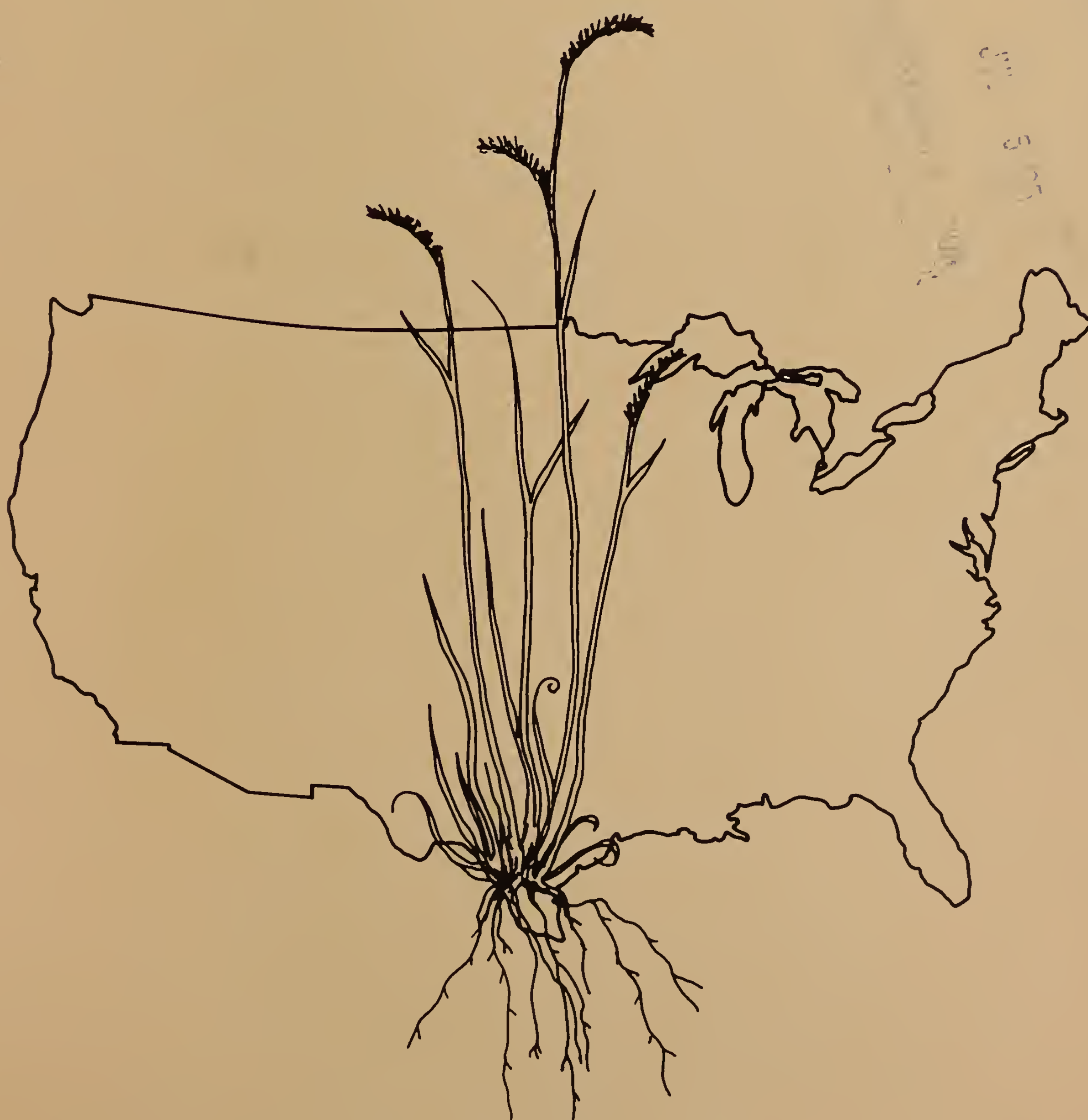

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Acronyms

ID	–	Interdisciplinary
RPA	–	Forest and Rangeland Renewable Resources Planning Act
NFMA	–	National Forest Management Act
FRES	–	Forest-Range Environmental Study
MRI	–	Multiple Resource Interactions
PNC	–	Potential Natural Community (classification system)
PC	–	Productivity Class
CC	–	Condition Class
RU	–	Resource Unit
ML	–	Management Level
SCS	–	Soil Conservation Service
MLRA	–	Major Land Resource Area
IBP	–	International Biological Program

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Abstract

Interdisciplinary team estimates of herbage/browse production used in the 1980 RPA Assessment were evaluated using three approaches. Estimates for nontimbered areas were mostly accurate; however, intrinsic relationships between forage production and productivity/condition classes were inconsistent. Production estimates for forested areas were more difficult to interpret, in part because of insufficient independent data. Intrinsic relationships also were inconsistent.

[1]*Headquarters is in Fort Collins, in cooperation with Colorado State University.*

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MANAGEMENT IMPLICATIONS

The multiresource data set developed by interdisciplinary (ID) teams for the Range and Multiple Resource Interaction parts of the 1980 RPA Assessment represented an immense task. It constitutes the only national-level multiresource data set available in the 1980s for assessments and appraisals. Moreover, there is little likelihood that this, or other intuitive data sets, will be soon replaced by more mechanistically quantitative models. If the Assessment data set is to maintain its usefulness, however, it should undergo updating and improvement. As expected, those ecosystems that are most commonly used for range livestock grazing are least needful of updating. Forested ecosystems comprise the majority of ecosystems whose forage production estimates fall outside of a proper conceptual framework.

Each of the three approaches taken in the present study has potential for amending different parts of the Assessment data set. The use of linear models to quantify the ID-team intuitive models in particular represents a consistent and documentable approach, especially for those ecosystems where independent data sources are lacking.

INTRODUCTION

During the past ten years, Congress has passed several laws that require federal agencies to make recurring assessments of present and projected resources coming from our Nation's forests and rangelands and future demands for these resources. The two laws assigning assessment responsibilities to the Forest Service are the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 (P.L. 93–378) as amended by the National Forest Management Act (NFMA) of 1976 (P.L. 94–588). The RPA requires both supply-side and demand-side analyses; this paper deals with the supply side.

The first assessment of U.S. forests and rangelands was released shortly after the passage of RPA and NFMA (USDA Forest Service 1977a). To a great extent, the chapter on range from this assessment was taken from an earlier efficiency analysis of the U.S. forest and rangeland base emphasizing range management options and entitled the Forest-Range Environmental Study or FRES (Forest-Range Task Force 1972).

The second assessment was published in January 1980 (USDA Forest Service 1980). In this paper it is referred to as the Assessment. It was more comprehensive than the first, principally because more time was available to plan for the job and obtain required information.

In both FRES and the Assessment, an interdisciplinary (ID) team approach was used to estimate present resource outputs. The multiresource data set developed for the Assessment was used in two chapters: Range and Multiple Resource Interactions (MRI) (USDA Forest Service 1980).

ID-team estimates of output levels for multiple products used both in FRES and the Assessment were a function of a hierarchical partitioning of the forest and rangeland base of the United States according to ecosystem classification, ownership, site potential, condition, and intensity of natural resource management. Table 1 shows these categories as defined in FRES and the Assessment. If only on the basis of the number of combinations possible when linking the categories, the Assessment obviously involved a greatly expanded undertaking.

For the Assessment, the ecological classification was based wholly on Küchler's (1964) Potential Natural Vegetation system. An additional vegetation type, mountain meadow, was added because of its importance to range livestock production on western National Forest lands. The amended classification system was renamed Potential Natural Communities (PNC) to distinguish it from Küchler's system.

Within each PNC the land base was subdivided by ownership, productivity class (PC), and condition class (CC) categories. Each had four possible designations in the Assessment (table 1), providing 64 possible unique resource units (RU) for each PNC. The RU constituted the basic land management unit used by the Assessment ID teams in making multiresource production estimates.

Management options were defined in the Assessment as a combination of practices describing a specific management intensity or level (ML) for each of the three resource output groups; timber, range, and wildlife (table 1). Management practices were chosen to be consistent with existing technology. Timber had six possible MLs (1–6), range had six (A-E, X), and wildlife had three (1–3). In general, the MLs selected for each RU had the same options or a subset of the options chosen for that PNC. Approximately 10 management triplets were specified for most PNCs.

Once ML goals were designated, specific management practices were selected for each RU to attain the desired ML. These practices were classified into range, timber, and wildlife practices (table 2). It should be noted, however, that such designations are somewhat artificial because most management practices affect all resource outputs. This concept of joint resource production is especially important for timber management practices on forested communities (Hof et al. 1985).

Table 1.—Classification categories used in the FRES and 1980 Assessment.

OWNERSHIP

FRES	Assessment
1 Forest Service	1 Forest Service
2 Other federal	2 Bureau of Land Management
3 Nonfederal	3 Other federal
	4 Nonfederal

PRODUCTIVITY CLASSES (PCs)

	Nontimbered *quartile*	Timbered *ft³/acre/yr*
1	High (1st)	120+
2	Medium high (2nd)	85–119
3	Medium low (3rd)	50–84
4	Low (4th)	0–49

CONDITION CLASSES (CCs)

	Nontimbered FRES	Nontimbered Assessment	Timbered[1]
1	Good	Good	Nonstocked
2	Fair	Fair	Seedlings and Saplings
3	Poor	Poor	Poles
4		Very Poor	Sawtimber

MANAGEMENT LEVELS (MLS)

FRES (Range practices only)

1. Environmental management without livestock
2. Environmental management with livestock
3. Extensive management of environment and livestock
4. Intensive management of environment and livestock
5. Environmental management with livestock production maximized
6. Exploitive management

1980 ASSESSMENT

Range

A.
B.
C.
D.
E.
X.

Same as for FRES; levels E and X were not considered in combination with any timber or wildlife management practices.

Timber

1. No commercial use
2. Minimal management without assured regeneration
3. Minimal management with assured regeneration
4. Level 3 with commercial thinning
5. Level 4 with precommercial thinning
6. Level 5 plus intensive silviculture such as fertilization

Wildlife

1. No management
2. Manipulation of vegetation
3. Level 2 with physical structure development

[1]*For technical description of these classes, see FSH 4809.11, Forest Survey Handbook.*

Thirteen resource outputs were estimated for the Assessment, nine less than under FRES. Of these, only nine categories were production levels. The others were in the form of indices or abstract percentages of land area. Those resource outputs defined quantitatively under FRES and the Assessment are listed in table 3.

In summary, the Assessment Range and MRI analyses were based on an intuitive (ID-team) approach, patterned after the earlier FRES. Inituitive models are not based on mechanistic mathematical descriptors or the statistical analysis of field data, but rely on experts to make estimates based on their training and experience (Joyce et al. 1983). Intuitive approaches are being increasingly used where environmental variables are difficult to quantify (Cooper and Zedler 1980). The next assessment, due by the end of 1989, will likely be conducted under a similar format, given the time constraint and lack of other national multiresource data sets. An important question to be asked by those responsible for the next assessment is whether the multiresource data set used in the 1980 Assessment is sufficiently accurate to be used again without modification, or whether

Table 2.—Management practices used in the 1980 assessment, by resource output group.

Management practice	Units/100 M acres
Range	
Fertilization	M acres
Irrigation	M acres
Water control	M acres
Mechanical vegetation control	
Low Cost	M acres
High cost	M acres
Vegetation manipulation	
Chemical	M acres
Biological	M acres
Fire	M acres
Debris disposal	M acres
Mechanical soil treatment	M acres
Seeding	M acres
Rodent control	M acres
Insect and disease control	M acres
Small water development	Sites
Large water development	Sites
Fence	Miles
Timber thinning	M acres
Timber	
Planting	M acres
Direct seeding	M acres
Site preparation for—	
Natural regeneration	M acres
Planting and seeding	M acres
Animal control for—	
Reforestation	M acres
Timber stand improvement	M acres
Precommercial thinning	M acres
Release and weeding	M acres
Fertilization of established stands	M acres
Seed production areas	M acres
Selection and care of superior trees	M acres
Prescribed burning to control understory	M acres
Access roads for timber production	Miles
Cutting method	
Shelterwood and seed tree	M acres
Clearcutting	M acres
Salvage	M acres
Commercial thinning	M acres
Selection (high-grading)	M acres
Selective	M acres
Wildlife	
Water developments—upland	Sites
Seeding and planting	M acres
Liming and fertilizing	M acres
Fencing	Miles
Prescribed burning—uplands	M acres
Clearing	M acres
Brush and shrub management	
Mechanical	M acres
Chemical	M acres
Biological	M acres
Pruning	M acres
Thinning—release	M acres
Mechanical soil treatment	M acres
Dens and nest structures	Structures
Perch and nest structures	Structures
Brushpiles and covers	Brushpiles
Streambank stabilizers	Sites

changes/updating will be required. A third alternative, building a completely new data set, may be infeasible under existing financial and time limitations.

The purpose of this study was to evaluate the herbage/browse production estimates used in the 1980 Assessment. Specifically, the objective was to ascertain whether these estimates were accurate, based on median values for each PNC in relation to other sources of information, and followed reasonable patterns within the PNCs in relation to changing PC and CC. In the book of procedures used by the ID teams (USDA Forest Service 1977b), herbage and browse production was defined as:

> Total air-dry weight of the current year's growth of leaves and twigs of shrubs, woody vines, and trees available for animal consumption, measured in pounds per acre to the nearest 100 pounds. For purposes of this exercise, herbage will also include growth of non-flowering, non-woody plants, such as ferns, mosses, lichens, and fungi.

This definition encompassed all plants, including members of thallophyte divisions and higher plants normally not considered as sources of forage. The only criterion for inclusion was availability. Such a definition is more inclusive than that commonly accepted in range management, which generally restricts the term "forage" to include only those plants having some food value to grazing or browsing animals (Sampson 1952). Consequently, the Assessment estimates would be expected to have larger values than anticipated for some PNCs, especially those with woody understories. In this paper, however, the term forage will be used synonymously with the Assessment definition of herbage and browse.

METHODS

By their nature, ID-team estimates present unique problems in data validation. First, assumptions built into the Assessment data, such as those to ameliorate effects of inclusions of unproductive areas within a PNC, make direct comparisons with field data difficult. The definition of herbage/browse used in the Assessment also constituted an assumption. Second, much published information comes from research studies, and as Bruce (1977) suggests, resource production data based on research plots are commonly different than actual production associated with the larger ecosystems such plots were designed to represent.

Perhaps the major impediment to validating the production estimates used in the 1980 Assessment resulted from the complex system of variables that the ID-teams had to consider, especially in terms of management practices. No independent data sets exist that depict the effects of site, successional status, and management on resource production. If the Assessment data for a given resource output are represented in an *n*-dimensional array, then the problem of comparing actual data with it becomes one of fitting these data into the array on the

Table 3. Resource categories estimated quantitatively in the FRES and 1980 Assessment.[1] (Units are on an acre^{-1} year $^{-1}$ basis, except for storm runoff.)

Resource category	FRES	Assessment
Livestock stocking rate	AUM	AUM
Herbage and browse production	Ton	Pound
Livestock output value	Dollar	--
Wild ruminant grazing	--	AUM
Wood growth	Cubic feet	Cubic feet
Wood harvest	--	Cubic feet
Water yield	Acre-foot	Inches
Quality water yield	Acre-foot	--
Storm runoff	Inches/storm^{-1}	Inches/storm^{-1}
Sediment	Ton	Ton
Dispersed recreation	Visitor-day	Visitor-day
Employment	Man-hour	--

[1]*Dash indicates no estimate made.*

basis of assumptions that are often tenuous. Given the constraints imposed by the problems outlined above, the following three procedures were employed here to evaluate the range data base: (1) intrinsic verification, (2) comparison with field research, and (3) comparison with Soil Conservation Service range site information.

First, the Assessment data were examined intrinsically for relationships between herbage and browse production and the various site and management descriptors, especially productivity and condition classes. Such relationships portray the formal expression of the ID teams' perceptions of production relationships of actual ecosystems. Consequently, the examination served as a verification of the theoretical "model" embodied in these perceptions (Nolan 1972). The next logical step, that of model validation, could not be undertaken because of the lack of real-systems data. Model validation tests a theoretical model's representation of a real system—which in this case constituted forage responses to different RUs and management.

With rare exceptions, as nonforested ecosystems retrogress from good/excellent to poor condition, actual forage production decreases even when palatability is not considered, because of immoderated environmental factors affecting plant growth (Mitchell 1983a). This qualitative relationship between range condition and primary production has been documented (Weaver and Albertson 1940, Strickler and Hall 1980). The few quantitative studies (Geobel and Cook 1960, Klipple and Costello 1960, Launchbaugh 1969) suggest the magnitude of reduction in productivity to be in the order of 15% to 50%, depending on PNC and the severity of depletion defining poor condition range. Reductions beyond 50% are always feasible because, by definition, the end point of retrogression is bare ground.

Information relating forage production to PC is, like that dealing with CC, inadequate for the purpose of making specific predictions. In what is perhaps the only paper dealing with this subject, Mueggler and Stewart (1981) examined 13 rangeland habitat types in Montana and found average production on poor sites to deviate around two-thirds of the average production on good sites for the same habitat type.

To summarize, from field research one can conclude that models of forage production on nonforested range should provide for decreases due to both range condition and site potential. Levels of reduction are uncertain, especially under the definition of herbage and browse provided in the 1980 Assessment; however, it appears that, when specific information is unavailable, production should be reduced on the order of one-fourth to one-half for both low site potential and poor range condition.

The relationship between forage production and CC on forest land has been well studied, especially in forest and woodland zones where grazing has been of historical importance (Ffolliott and Clary 1982). Basically, production decreases in response to overstory development in the tree canopy. Unfortunately, little is known concerning trade-offs between forage production and site index (i.e., PC) on timbered range (Clary et al. 1966), and what has been published provides ambivalent conclusions (Basile 1971).

A linear model was used to describe numerically the association between PC and CC as they affected forage production estimates in the Assessment.

$$Y_{ij} = \alpha + \beta_i(PC)_i + \gamma_j(CC)_j + \delta_{ij}(PC)_i(CC)_j \qquad (1)$$

Y_{ij} was forage production for the i^{th} PC and j^{th} CC. The four parameter sets, α, β, γ, δ, represented the intercept, main effect of PC, main effect of CC, and the PC-CC interaction. In the model, PC and CC were dummy variables. Since only one observation, the ID-team estimate, existed per cell, the model provided a perfect fit of the data set, and the error sum of squares was zero.

Using a model to portray forage production in relation to PC and CC served three useful purposes. First, it quantified the influence that PC had in relation to CC. Second, it showed whether a synergistic effect existed between PC and CC to increase (or decrease) forage production on higher class sites in good condition. Third,

the model made missing data and apparent data entry errors (either in the Assessment data base or this study) easy to discern, primarily because they created outliers among the interaction coefficients, δ_{ij}.

The ID teams taking part in the 1980 Range and Multiple Resource Interaction Assessments were trained and completed their work in one of two sequential workshops, held both at Fort Collins, Colo., and Athens, Ga. The two Fort Collins workshops were responsible for the western PNCs, while the Athens workshops handled the eastern PNCs. There were six team leaders in Fort Collins and four in Athens. Each leader was responsible for two ID teams which met in successive 2-week periods. Individual team members were assigned PNCs, and asked to bring data and other background information to their workshop.

As part of the process for intrinsically evaluating the data set, the PNC linear model coefficients were subjectively compared on the basis of (1) where the ID teams assembled, (2) between ID teams within the two workshop locations, and (3) between 2-week periods for the Fort Collins workshops only. Specifically, the comparison was made to see whether visible differences existed depending on (1) where the ID teams received training, (2) who the ID-team leaders were, or (3) the experience each ID-team leader obtained after going through one 2-week period. To do this, the linear model coefficients were examined for main (PC versus CC) effect and level of interaction. The model coefficients for each PNC were classified into one of five main-effect categories and three interaction categories.

Main-effect categories:

P+	PC dominates, CC has no effect
P	PC effect exceeds CC effect
=	PC and CC effects are approximately equal
C	CC effect exceeds PC effect
C+	CC dominates, PC has no effect.

Interaction categories:

0	No interaction effect (9 cells blank)
+	Weak interaction effect (3–8 cells blank)
+ +	Strong interaction effect (< 3 cells blank)

The resulting tabular information was then scrutinized for explicit patterns and relationships that would portray the confounding effects being sought.

A second evaluation procedure consisted of comparing actual field data, obtained primarily from research reports, with Assessment estimates wherever commensurable data became available. In all instances, published field data were insufficient to adequately describe the forage production response surfaces represented in the Assessment by the various site/management descriptors. Therefore, comparisons, themselves, became intuitive in nature.

Finally, Assessment data were compared with herbage production estimates contained in range site descriptions developed by the Soil Conservation Service (SCS) of USDA. Under the range site concept, rangeland is classified according to its potential plant community composition and productivity (Shiflet 1973). The classification scheme resembles that of the habitat type used in classifying forests (Daubenmire 1952), except that productivity is not a factor in defining habitat types.

Descriptions have been written for hundreds of range sites, mostly located within the 17 western range states. They include estimates of average forage production, during both favorable and unfavorable years, by range condition. Although the forage production estimates are based on actual field data, they are intuitive to the extent that each represents a judgment by a locally experienced range conservationist who must synthesize these information sources into two single values.

Range site descriptions are developed within individual states under the auspices of each SCS state office. However, they are categorized under a hierarchical classification according to land resource regions and major land resource areas (MLRA) (USDA SCS 1981). MLRAs are differentiated on the basis of soils, climate, water resources, and land uses, and are not affected by political boundaries. Similar range sites can occur, therefore, in different states within the same MLRA. Sometimes they also are found in different MLRAs.

Range site descriptions are more detailed than PNCs, even when the latter are stratified by PC. Because of this disparity, an algorithm was required to match Assessment data with their respective range site estimates. The procedure consisted of matching PNCs and MLRAs on their respective maps, and choosing target MLRAs for more detailed analysis. Then, within an MLRA, range sites were selected to represent the entire span of forage on understory production within that MLRA.

Selection of range sites was based principally on species composition at climax (i.e., CC1), as identified in each range site description. (For a discussion of the concepts of succession and climax, see Daubenmire 1968.) When only a few pertinent range sites were available, all were listed for comparison purposes. Alternatively, when many range sites comprised an MLRA, a sample was selected for comparison using the following guidelines:

1. The sample represented the range of production.
2. The sample depicted the sites most representative of the MLRA, especially where production was not evenly or normally distributed across range sites.
3. Sites selected for exclusion tended to be of minor importance in terms of land area.

Of the 107 PNCs contained in the Assessment data set, herbage and browse production estimates are contained in all but two, desert and mangrove. For purposes of this study, however, only major forage-producing PNCs were evaluated, i.e., those that are important as rangeland (Stoddart et al. 1975) because of their species composition or size. Table 4 lists the 32 PNCs examined. They account for more than two-thirds of the land area and three-fourths of the total mass of forage produced, according to the Assessment data set. Of these 32, only 24 could be compared to SCS range site descriptions because of the lack of range site descriptions for forested communities, especially in the eastern United

Table 4.—List of PNCs for which herbage/browse production estimates used in the Assessment were examined.

PNC	Shrub and grassland	PNC	Forest and woodland
32	Great Basin Sagebrush	2	Cedar-Hemlock-Douglas-fir[1]
34	Saltbush-Greasewood	5	Mixed Conifer[1]
41	California Steppe	10	Western Ponderosa
47	Grama-Galleta Steppe	11	Douglas-fir
49	Sagebrush Steppe	14	Western Spruce-Fir[1]
52	Grama-Tabosa Shrubsteppe	21	Pinyon-Juniper Woodland
53	Trans-Pecos Shrub Savanna	26	California Oakwood
54	Mesquite-Acacia Savanna	91	Oak-Hickory[1]
56	Foothills Prairie	95	Appalachian Oak[1]
57	Grama-Needlegrass-Wheatgrass	101	Oak-Hickory-Pine[1]
58	Grama-Buffalo Grass	102	Southern Mixed Forest[1]
59	Wheatgrass-Needlegrass	103	Southern Floodplain Forest[1]
60	Wheatgrass-Bluestem-Needlegrass		
62	Bluestem-Grama Prairie		
66	Bluestem Prairie		
67	Nebraska Sandhills Prairie		
75	Cross Timbers		
76	Mesquite-Buffalo Grass		
77	Juniper-Oak Savanna		
107	Mountain Meadow		

[1]*No comparable SCS site descriptions available.*

States. In addition to those listed in table 4, several other PNCs were included in the comparison with research data, but only to further understanding of the results.

RESULTS

Intrinsic Relationships

An examination of the way in which herbage and browse production estimates were effected by PC and CC provided an interesting perspective on the nature of the Assessment data set. In general terms, production on grassland-shrubland PNCs varied more widely in response to PC than it did with changing CC. Alternatively, on forested and woodland PNCs, the opposite occurred. Herbage and browse production for selected MLs for the PNCs evaluated are presented in appendix 1 by PC and CC.

Nonforested PNCs

Twenty nonforested PNCs were examined (table 4). Sixteen of these were dominated by graminoids, either as grasslands or under mostly open shrub or tree synusiae. As climax communities, about one-half were represented by warm-season, sod-forming grasses, and the other half by cool-season bunchgrasses. Together, they encompassed a wide variety of ecosystems, not only in their structure but in their successional dynamics.

Five of the non-forested PNCs (32, 41, 47, 49, 52) showed no decline in productivity across CC (table 5). Although they are grouped together in terms of PNC identification number, they possessed no common characteristics that allowed them to be clustered ecologically. The proportional relationship of forage production to PC was similar for each of these five PNCs; i.e., production for PC1 tended to be three to five times higher than for PC4. Consequently, the conceptual forage production model for these five PNCs embodied in the ID-team estimates states that production is not affected by range condition; however, site potential can have a great influence.

Four PNCs (56–59) had identical main-effect coefficients for both PC and CC (table 5); i.e., forage production responded equally to changing PC and CC. Each of the four PNCs had similar interaction coefficients, suggesting a positive synergistic effect between PC and CC possessing the same symmetry as the main effects. Although the PNCs, numbered sequentially, were contiguous to one another in the northern and central Great Plains, they fall into two groups ecologically and suggest an ID-team effect. PNCs 56, 57, and 59 were dominated by cool-season wheatgrasses and needlegrasses at climax, while PNC 58 was represented by blue grama and buffalograss, warm-season sod grasses of the high plains (Küchler 1964). In fact, the species composition of PNC 56 resembles that of PNC 49 much more closely than it does PNC 58.

Only one PNC, 54, showed a greater main effect for CC than for PC (table 5). In addition, a strong positive interaction effect between PC and CC was depicted in the model for PNC 54. The ID team had apparently considered the influence of increasing woody growth during retrogression (i.e., decreasing CC) to a greater extent than the ID teams evaluating other PNCs with a brush or savanna overstory, such as PNC 32, 49, 76, and 77.

The remaining ten nonforested PNCs all could be characterized by greater main effects for PC than for CC (table 5). In ranking these PNCs by the ratios of model

Table 5.—Coefficients of linear model of forage production estimates for selected PNCs, as based on ID-team estimates, contained in the 1980 RPA data base.

PNC-ML	α_0	β_1	β_2	β_3	γ_1	γ_2	γ_3	δ_{11}	δ_{12}	δ_{13}	δ_{21}	δ_{22}	δ_{23}	δ_{31}	δ_{32}	δ_{33}
Grassland-Shrubland PNCs																
32C	400	1100	800	400												
34C	0	750	500	250	250	150	50									
41C	800	2400	2000	800												
41D	900	3600	2800	900												
47B	200	300	200	100												
47D	200	300	300	100				100	100	100						
49C	500	1500	1000	500												
49D	0	2200	1600	1100	0	0	0	300	300	0	200	200	0	100	100	100
52B	100	400	200	100												
53C	200	1000	0[1]	400	300	200	100	200	200	100						
53D	200	1800	0[1]	1000	300	200	100	−200	−200	−100				−300	−200	−100
54B	200	300	200	100	800	500	300	1200	900	400	800	600	200	400	300	100
54E	300	400	300	100	900	600	400	900	1100	500	900	700	200	500	400	200
56C	200	300	200	100	300	200	100	1200	800	400	700	500	300	400	300	100
57C	100	300	200	100	300	200	100	900	600	300	600	400	200	300	200	100
58C	100	300	200	100	300	200	100	300	200	100	200	100	100	100	100	
59C	100	500	300	100	500	300	100	1400	800	300	800	600	300	300	300	200
59D	100	800	400	200	800	500	200	2000	1100	400	1200	900	500	400	400	200
60C	600	900	600	300	600	400	200	900	600	300	600	400	200	300	200	100
60D	700	1000	600	300	500	300	200	900	600	300	700	500	300	300	200	100
62C	800	1200	800	400	400	300	100	600	400	200	400	300	200	200	100	100
62D	1000	1400	900	400	200	100	100	400	200	300	300	200	300	200	100	200
66C	1000	4000	2500	1200	700	600	400	1100	1100	100	200	200	−100	100	0	0
66D	1900	4900	2500	1200	400	200	0	200	200	0	200	200	0	0	0	0
67C	600	3300	2200	1100	400	200	0	0	−100	0	0	100	0	0	100	0
75C	900	1500	900	600	1200	800	400	1200	800	400	900	600	300	300	200	100
76B	800	2200	1500	700	400	300	200	100	100	0	0	0	0	100	100	0
76D	800	2800	2000	700	400	300	200	200	200	0	0	−500	0	100	100	0
77D	1200	3600	1200	600	1200	600	0	0	−600	−1200	1200	600	0	600	0	0
107C	200	2800	2000	800	800	400	200	200	200	0	0	0	−200	200	200	0
107D	400	3100	2000	800	700	400	200	300	100	100	300	200	0	300	200	0
Forested PNCs																
2A2	100				1400	300	−50	1500	100		1000	100		500	100	
2A5	100				1400	300	−50	500	100	50	200	100	50		100	50
5B	1000	−500	−500	−400	2000	1500	300	3500	3000	200	2000	1800	100	−600	−400	−200
10B	400				400	−300	−200									
10D	600				300	−500	−100									
11B	100	600	600	400	400	200	100	2900	1100	200	2900	1100	200	800	200	−100
14B3	0				1200	500	100	3000	2500	900	1800	1000	300	1000	500	200
14C5	100	400			1100	900	200	2400	1600	900	2000	1000	700	1000	600	500
21B	100	500	300	100	100	100		200	100	100	200	100	100	200	100	100
21D	100	700	600	300	200	100	100	200	200	100	100	100		100	100	
26B	2900					300	100									
26D	3500				700	1000	100									
91A	300				900	300	400	−400	−300	−500	−400	−300	−500	−200	−200	−200
91D	1500	2500	2500	500										−500		
95C	600	−100	−100	−100		−100	−100	300	200	100	300	200	100	200	200	100
101B	600	−100	−200	−100	400	−400		300	900	100	400	1000	300	300	300	
102A3	400	800	400	400	600	400		1200	600		600	300		600	300	
102B4	1000	500				500	−200		200	−100						
102A6	1000	500			−500	500	−200	−250	200	−100						
103A2	100	200	200	100	200	500		500	100	−100	500	100	−100	400		
103E	12000															

[1]*Zero value in main effect due to missing data.*

coefficients for PC1:CC1, the median value obtained was approximately 4.25:1. Two PNCs, 60 and 75, approached the symmetry between PC and CC found in the four previously discussed. At the other extreme, PNC 66, under intensive range management, depicted a relationship wherein PC affected forage production over CC by more than an order of magnitude.

Except for situations where data were missing or apparent data entry errors had occurred, all interaction coefficients were positive and reasonably consistent, indicating a positive synergistic effect between increasing PC and CC. Missing data for PC2 were found in PNC 53. This exclusion can be explained by the absence of PC2 from the land base of PNC 53. In the automated editing

process, all production estimates were dropped from the data base if the RU did not exist in the land base. Apparent data outliers, i.e., those disrupting the smooth response surface of production in relation to PC versus CC, were found in seven of the selected nonforested PNCs (table 6).

Table 6.—List of PNCs used in the 1980 Assessment having forage production estimates that are questionable, based on internal inconsistencies.

PNC	Range-Forest ML	Location of outlier PC	CC
Nonforested PNCs			
54	E	1	2
62	D	1, 2, 3	2 versus 3
66	C	1	Magnitude of drop from CC2 to CC3
67	C	1	2
76	D	2	2
77	D	1	4
107	A	2	4
Forested PNCs			
91	D	3	1
101	B	4	2

Forested PNCs

Unlike the situation for nonforested PNCs, model coefficients describing forage production in relation to PC and CC on forested PNCs were irregular and more difficult to interpret. For example, main-effect coefficients on half of the 12 PNCs examined contained negative values, which meant that forage production actually decreased at some point with increasing PC or CC (table 5). Such an inverse association between forage productivity and PC may be seen in PNC 5, while PNC 10 portrays the same situation in relation to CC.

A possible explanation exists for forage production increasing across decreasing PC; i.e., a low-site stand might tend to be more open because of limiting ecological factors, such as thin soil, resulting in less light attenuation by the forest canopy and increased understory growth (Ffolliot and Clary 1982). No comparable explanation is evident for an inverse relationship between productivity and CC, however.

In general, CC had a greater main-effect influence on production than did PC (table 5). This intuitive model provided a logical description of what actually occurs in forested ecosystems where the controlling factor is often the overstory canopy (Ffolliott and Clary 1982). Exceptions were confined for the most part to management triplets containing intensive range management levels (i.e., D), which ostensibly included timber thinning and chemical vegetation manipulation practices.

PNCs 11, 21, and 102 showed tendencies for a larger main effect due to PC at less than intensive levels of range management. Of these, PNC 21 may most reasonably be expected to respond to PC as depicted because of the wide diversity of sites occupied by pinyon-juniper associations. Jameson and Dodd (1969), for instance, showed that production of herbaceous vegetation varies widely in Arizona pinyon-juniper communities, depending on soil type (i.e., PC).

Identifying apparent data entry errors or other outliers proved to be somewhat more difficult for the forested PNCs because the interaction coefficients varied widely in reaction to the inverse relationships between forage production and PC/CC, as discussed above. The two forested PNCs having identifiable outliers are shown in table 6.

The inspection of linear model coefficients to compare ID-team characteristics (locations of training, ID-team leader, and experience effect resulting from successive workshops) provided interesting results. For nonforested ecosystems there was a tendency to confound the team leader and experience effects due to allocation of PNCs to groups for those PNCs which we evaluated (table 7). That is, five of the seven PNCs covered in the first session were handled by ID teams 2 and 5. During

Table 7.—Relationships between linear model coefficients, as expressed by main-effect emphasis and degree of interaction, and ID-team characteristics as identified in the 1980 RPA Assessment

ID-team location	Workshop session	ID-team number	PNC	Main effect[1]	Degree of interaction[1]
		Nonforested PNCs[2]			
Fort Collins	1	1	47	P+	0
		2	56	P-C	++
		2	57	P-C	++
		4	41	P+	0
		5	32	P+	0
		5	34	P	0
		5	49	P+	0
	2	1	52	P+	0
		1	53	P	+
		2	59	P-C	++
		4	107	P	+
		5	67	P	+
		6	58	P-C	++
		6	60	P	+
		6	62	P	++
		6	76	P	+
		Forested PNCs			
Fort Collins	1	2	11	P	++
	2	2	14	C+	++
	1	3	2	C+	+
	1	3	10	C+	0
	1	4	26	C+	0
	1	5	21	P	++
	1	6	5	C+	++
Athens	1	1	102	P-C	+
	2	1	95	P-C	++
	1	3	91	C+	++
	1	3	101	P-C	++
	2	3	103	P-C	+

[1]*Categories have been defined in the Methods Section.*

[2]*Nonforested PNCs examined at Athens included 54, 66, 75, and 77.*

[3]*Fort Collins Workshop 1, March 21 to April 8, 1977*
Workshop 2, April 11, to April 22, 1977
Athens Workshop 1, March 29 to April 15, 1977
Workshop 2, April 12 to April 29, 1977.

the second session, however, most of the PNCs (six of nine) were handled by two different ID teams (numbers 1 and 6). Therefore, there was little opportunity to examine the ID team-session interaction.

Results of the comparison of linear model coefficients with ID-team training/work site, ID-team (leader) identification, and ID-team leader experience level (period 1 versus period 2) are presented in Table 7. Looking first at nonforested PNCs addressed in Fort Collins, it is obvious that, except for the estimates provided by team 2 and one other PNC (34), all of the linear models developed during the first session contained main-effect responses to PC only and had no interaction effects. On the other hand, models developed during the second session contained, with one exception (PNC 52), main-effect responses to both PC and CC and had interaction effects. There were insufficient nonforested PNCs from the Athens site to warrant examination.

While the nonforested situation was related to workshop session number (confounded with ID-team effect), model coefficients emanating from ID-team estimates of forested PNCs did not (table 7). Here, the major division appeared to result from location. The ID-team meeting at Fort Collins, with two exceptions (PNCs 11 and 21), found CC to provide the only nonnegative main effects, while the Athens-based ID teams tended to provide main-effect responses to both PC and CC. Several of the main-effect coefficients were negative, however, making comparative interpretations more difficult. Interaction effects were present for nearly every forested PNC.

Comparison with Field Data

Sagebrush-Grass Ecosystems (PNCs 32 and 49).—Küchler differentiated between PNCs 32 and 49 by stating that the former was a shrub community and the latter was a grassland topped by a shrub synusia; i.e., the differentiation was on the basis of grass abundance. Other authors, however, have made no attempt to divide the sagebrush-grass region into major subtypes (Tisdale and Hironaka 1981).

Although the sagebrush-grass region has received extensive research, little has been published on total production of native vegetation. For example, Robertson (1971) compared production of grass species on a native sagebrush site in northern Nevada to one reseeded with crested wheatgrass. His reported values of 200 and 925 lb/acre, respectively, unfortunately do not include forb and shrub production. Robertson's site had been ungrazed for 30 years, but had been eroded during earlier times; therefore, it logically would have fit the PC-CC-ML code of 3–1–A or 4–1–A. These values were 800 and 400 lb/acre, respectively, for PNC 32 and 1,000 and 500 lb/acre for PNC 49. (Note: Recall from previous section that CC had no effect on forage production in the Assessment data base for the two sagebrush PNCs.)

In an earlier study Passey and Hugie (1963) followed total herbage and shrub biomass for 4 years on a protected, ungrazed site in southern Idaho. They recorded values of approximately 600–1,000 lb/acre, with an average of 800 lb/acre. Based on the study area description, one would classify their site as PNC 49 with a PC-CC-ML of 1–1–A or 2–1–A for comparison purposes; the Assessment estimates were 2,000 and 1,500 lb/acre.

Blaisdell (1958) reported on 20 years of vegetation composition and yield data collected from large enclosures at the U.S. Sheep Station in eastern Idaho. His estimate of average total grass, forb, and shrub peak biomass was 820 lb/acre, which closely approaches the estimate provided by Passey and Hugie (1963) and tends to corroborate the conclusion that Assessment estimates for productive sites (PC = 1,2) in the sagebrush-grass region appear too high.

Mixed-Grass Plains (PNCs 59 and 57).—During the early 1970s, two comprehensive study sites were maintained on the mixed-grass Great Plains under the auspices of the International Biological Program (IBP). In western North Dakota, Lauenroth and Whitman (1977) estimated total above-ground production to range from 2,150 to 2,700 lb/acre on an ungrazed site equivalent to PNC 59 in good condition (PC-CC-ML = 2–1–A). The Assessment estimate for this site was 1,700 lb/acre.

The Cottonwood Range Field Station, located in western South Dakota (PNC 59), has maintained experimental pastures that have been subjected, nearly continuously, to light, moderate, and heavy grazing since 1942. By the mid–1950s, these pastures were in low excellent, good, and fair conditions, respectively (Lewis et al. 1956). At that time, Lewis et al. (1956) measured forage production in the draws (PC1), on north slopes (PC2), south slopes (PC3), and ridges (PC4). Table 8 compares their sample means with comparable Assessment estimates. Subjectively, it appears that the Assessment figures are reasonable for the combinations of PC1 and 2, and CC1 and 2; however, they are increasingly underestimated at the lower combinations of PC and CC.

Reed and Peterson (1961) summarized a grazing study lasting from 1932 to 1946 on mixed-grass prairie near Miles City, Mont. (PNC 57). They reported production estimates of bench sites (PC3) and bottomland (PC1) under both light (CC1) and heavy (CC3) grazing (table 9). Their values are reasonably close to the ID-team

Table 8.—Average (1952-1955) forage production (lb/acre) on experimental pastures at the Cottonwood Range Field Station (South Dakota) in comparison to assessment estimates (ML = C).

	PC			
CC	Draws 1	N-Slopes 2	S-Slopes 3	Ridges 4
Field data (Lewis et al. 1956)				
1	2885	1389	1289	1059
2	2231	1343	1300	1009
3	2509	1188	1098	1069
Assessment estimates (PNC 59: Wheatgrass-Needlegrass)				
1	2500	1700	1000	600
2	1700	1300	800	400
3	1000	800	500	200

Table 9.—Forage production (lb/acre) after fifteen years of grazing research on Mixed-Grass Prairie near Miles City, Mont., in comparison to assessment estimates (ML = C).

	PC	
CC	Bottomland 1	Benches 3
Field data (Reed and Peterson 1961)		
1	1139	517
3	770	395
Assessment estimates (PNC 57: Grama-Needlegrass-Wheatgrass)		
1	1900	800
3	800	400

estimates in the Assessment, and would have probably been closer if 1945, the year in which their forage biomass estimates were taken, had not been a dry year.

Short-grass Plains (PNC 58).—The cornerstone of range research on the shortgrass plains has been conducted at the Central Plains Experimental Range near Nunn, Colo. Klipple and Costello (1960) summarized a decade of herbage production during the 1940s on pastures grazed at light, moderate, and heavy intensities. They found total production of all vegetation to remain the same for lightly and moderately grazed pastures (i.e., about 600–650 lb/acre), but to decrease by one-third under heavy grazing (420 lb/acre). These values fall into the mid-range of ID-team estimates for PNC 58; however, the proportional drop from CC1 to CC4 within a given PC somewhat exceeds the 33% cited by Klipple and Costello (1960), depending on whether the heavily grazed pastures fell in CC3 or CC4. No pastures approached the 800–1,000 lb/acre contained in the Assessment under high combinations of PC and CC for PNC 58.

Sandhills Prairie (PNCs 67 and 63).—At the Eastern Colorado Range Station near Akron, total herbage yield on lightly (CC1), moderately (CC2), and heavily (CC3) grazed pastures were monitored between 1964 and 1968. The investigators (Sims et al. 1976) reported averages of 1,430, 1,210, and 930 lb/acre for the three respective pastures. However, production had evidently not stabilized on the heavily grazed pasture by the study's end, and the actual disparity between CC1 and CC3 may be somewhat greater. According to L. Rittenhouse of Colorado State University (personal communication), the averages provided by Sims et al. (1976) are reasonable for the western (drier) end of the sandhill prairie region.

Assessment estimates for PNC 63 (sandsage-bluestem prairie; not discussed elsewhere in this report) closely track the Akron research results. Taking an "average" PC of 2.5, production estimates for CC1, CC2, and CC3 were 1,400, 1,350, and 1,150 lb/acre, respectively. Those for the true Nebraska sandhills prairie (PNC 67), however, are approximately double those for PNC 63, except for PC4, where they are comparable.

Tallgrass or True Prairie (PNC 66).—Although it originally constituted a vast area from the Canadian border to Texas and eastward (wedgelike) as far as Indiana (Küchler 1964), the tallgrass prairie has been reduced to small, scattered remnants over much of its range. The Flint Hills of Kansas and Osage Hills of Oklahoma constitute the only appreciable tracts of native prairie left, primarily because they are underlain by soils too rocky to plow. Of the original 250 million acres, less than 20 million acres remain in native vegetation (USDA Forest Service 1936). Much of the true prairie has subsisted in good condition, however, because of its recovery from drought and grazing pressure during earlier years (Weaver and Hansen 1941).

In northwestern Minnesota, Smeins and Olsen (1970) measured peak standing crop of an upland, moist tallgrass prairie site in pristine condition at 3,980 lb/acre. In central Missouri, Kucera et al. (1967) found production to vary according to fire, especially in the eastern parts of the prairie region. Peak standing crop on unburned sites was approximately 4,500 lb/acre, while it increased by 15% to 100% on burned sites.

Old (1969) corroborated Kucera et al.'s work in eastern Illinois, where she reported herbage biomass levels of 4,750 lb/acre on recently burned prairie and 2,400–3,000 lb/acre on burns 3 to 4 years old. In Iowa, Ehrenreich and Aikman (1963) reported that burning did not greatly increase production of native prairie, i.e., 3,300 lb/acre on unburned plots versus 3,600–4,250 lb/acre on burned plots.

The importance of what is meant by production (Mitchell 1983a) is nowhere greater than when considering the true prairie. Here, the difference between production rates and peak community biomass for prairie ecosystems can be substantial. Parton and Risser (1980), for example, predicted net aboveground primary production on an Oklahoma tallgrass prairie to be 4,830 lb/acre/yr under no grazing, while peak standing crop was only 2,460 lb/acre. Under moderate grazing, production and peak standing crop were estimated at 4,980 lb/acre/yr and 2,290 lb/acre, respectively. The production estimates presented in this report were apparently, for the most part, measures of peak standing crop or end of growing season biomass.

The literature, as shown above, reports a broad range of herbage production across the true prairie, depending on a number of interacting factors like site factors and fire history. The ID-team estimates for PNC 66 nicely bracket these production figures. For example, given PC2 and range ML = C, herbage production estimates decline from 4,400 lb/acre under CC1 to 3,500 lb/acre under CC4. As with some other PNCs evaluated, the highest (PC1, CC1; PC1, CC2) and lowest (PC4) production estimates appear somewhat extreme; however, literature values are not available to either support or refute them.

Cedar-Hemlock Zone (PNCs 2 and 12).—In the Pacific Northwest, cedar-hemlock sites (PNC 2) are often dominated by Douglas-fir, except on old-growth stands (Franklin and Dyrness 1973). Understory abundance is primarily a function of overstory canopy closure in these dense forests; an abundance of forage exists in the open-

ings, while closed stands are considered unsuitable for grazing (Mitchell 1983b).

Long and Turner (1975) described a decreasing exponential relationship between overstory canopy and understory shrub abundance in young, productive Douglas-fir stands in western Washington (PC1). At a stand age of 20 years (CC2), understory biomass, including woody material, was estimated at 6,000 lb/acre. Two older stands (CC3) had understory biomass levels of 2,450 and 3,780 lb/acre, still a substantial amount.

In a similar study, Webber (1977) found understory biomass, approximately 350 lb/acre, to be much less than that reported by Long and Turner. However, Webber's stand, estimated to be 15–20 years old, was overstocked with trees and located on an area of low site potential (PC4). Natural regeneration occurred on the sites of both studies (forest ML = 2).

The Assessment data base is extremely low compared to Long and Turner (1975), but reflects Webber's (1977) results accurately (appendix 1.21). Understory production estimates for CC1 in comparison to CC2 reveal a possible inaccuracy in how the ID teams viewed forage production in relation to these two forest CCs. To go from a nonstocked state (CC1) to one where seedlings have become established (CC2) has no significant detrimental effect on actual forage production under most conditions. In fact, where shrubs dominate the understory, forage biomass actually peaks from 5 to 30 years after timber harvest (Hedrick et al. 1968). In other words, the biggest loss in forage production generally comes between CC3 and CC4. However, of the forested PNCs evaluated in this report, only one (PNC 5: mixed conifer) followed such a pattern.

The cedar-hemlock zone in the northern Rockies (PNC 12) is synecologically similar to PNC 2 (Daubenmire 1943). Both are characterized by the same climax and similar seral trees species, and most understory unions are dominated by tall shrubs. Therefore, forage production would also be expected to be reasonably comparable. For example, Eissenstat and Mitchell (1983) measured understory biomass on a northern Idaho clearcut two years after harvest (CC1 or 2; seedlings had been planted the previous year), both under natural vegetation establishment and following seeding with a grass mixture of orchard grass and timothy. Peak biomass on the control plots averaged 2,300–2,500 lb/acre both on slope sites (PC = 2–3) and bottomland (PC1), most of it in the form of thistles and annuals. On the grass treatment, production was unchanged on slopes, but had increased to 3,100 lb/acre on bottomland. In all cases except the bottomland seeding, shrubs showed signs of rapid growth, likely leading to their prevalence in 4 to 6 years at biomass levels not unlike that reported for Cascade forests (Long and Turner 1975).

Forage production estimates for PNCs 2 and 12, however, are neither similar nor consistent. In general, estimates for PNC 12 are 50% higher than those for PNC 2. In addition, the biggest drop-off between CC is between CC1 and CC2 within PNC 2, and between CC2 and CC3 within PNC 12.

Ponderosa Pine (PNCs 10, 17, and 18).—Ponderosa pine may be found in the western United States from Canada to Mexico. It is a dominant or codominant on six of Küchler's (1964) forested PNCs; mixed-conifer (PNC 5), western ponderosa (10), eastern ponderosa (15), Black Hills pine (16), pine-Douglas-fir (17), and Arizona pine (18). Understory vegetation associated with these PNCs is diversified, ranging from tall shrubs to sparse, herbaceous unions, and research has shown herbage yields to be, likewise, extremely variable.

Currie (1975) has reviewed the literature on ponderosa pine ranges in the central Rockies. He noted that, on sites with bunchgrass understory unions, annual forage production decreases from a maximum of 1,600 lb/acre on protected, open pastures (CC1 or 2), to 1,200 lb/acre on open pastures under moderate grazing, to 50 lb/acre on sites under dense timber. The Assessment data base (PNC 17) followed these values closely except for CC4, which was higher; i.e., 300 versus 50 lb/acre.

In northern Arizona (PNC 18), Pearson and Jameson (1967) depicted an inverse exponential relationship between herbage production and ponderosa pine basal area. On nonstocked stands (CC1), they estimated understory biomass at 600–700 lb/acre. For CC2, 3, and 4, their estimates were approximately 500, 250, and 50–100 lb/acre, respectively. Ffolliott and Clary (1974) also evaluated herbage production in PNC 18, and found it to be related not only to overstory, but to precipitation as well. For example, on nonstocked stands, understory biomass ranged from 500 lb/acre under 16 inches of precipitation (PC4) to over 1,000 lb/acre in the most mesic sites (PC1). Average production for all sites was about 750 lb/acre, which agreed with Pearson and Jameson's (1967) results.

Assessment forage production estimates for PNC 18 were incomplete, lacking entries for PC1 to CC1 and PC2 to CC1. Neverthless, the magnitude and trend of values that were available for CC1 followed the research results discussed above. Unfortunately, as shown several times previously on forested PNCs, the Assessment production estimates drop off more rapidly between CC1 and CC2 than relevant research indicates, and then remain mostly constant through CC4. The Assessment estimates were, consequently, much lower for CC2 and slightly high for CC4.

McConnell and Smith (1970) studied the response of understory to ponderosa pine thinning on an intermediately productive site (PNC 10, PC3) in eastern Washington. After 8 years, they estimated production under CC3 (20–60% percent pine canopy) to range from 250 to 500 lb/acre. Unthinned plots (CC4) produced about 75 lb/acre each year. The Assessment estimates for PNC 10 were characterized by the same improper response to CC as described for PNC 18.

Finally, in South Dakota's Black Hills (PNC 16), Pase (1958) examined herbage production in relation to overstory crown cover. He measured biomass in clearcuts (CC1) at 2,160 lb/acre, while under the densest stands (crown cover 70%) it had dropped to 40 lb/acre. Through interpolation of Pase's results understory

biomass for CC2 and CC3 was estimated at 1,360 and 300–500 lb/acre, respectively. Assessment (PNC 16) estimates were much lower than those of Pase for CC1 and CC2, but were higher for CC4; i.e., 1,000–1,200; 300–800; and 100–200 lb/acre, respectively. Again, production dropped too fast between CC1 and CC2, and leveled off too much for CC3 and CC4.

Pinyon-Juniper (PNC 21).—The pinyon-juniper type is widely distributed throughout the western United States. It is characterized by ecologically significant variations in precipitation and soils (Springfield 1976). Density of climax tree stands vary from dense stands of pinyon with essentially no understory to juniper savannas with excellent herbaceous cover. As a result, forage production varies widely, even within a given RU-ML combination. Jameson and Dodd (1969), for example, reported that potential forage production on soils derived from basalt, limestone, and some shales were 1,200–1,500; 600–1,200; and 500–800 lb/acre, respectively. Obviously, any attempt to integrate these variables into one estimator for the entire pinyon-juniper type would be a herculean task if it were to be based on scientific evidence.

Numerous authors (e.g., Arnold and Schroeder 1955, Jameson 1967, Pieper 1968, Clary 1971) have examined forage production within PNC 21, and their results, although variant, delineate production levels similar to those listed above (Jameson and Dodd 1969) for CC1, dropping off to 50–100 lb/acre for CC4. Such values are in remarkably close agreement with the ID-team's estimates for PNC 21 in the Assessment.

Oak-Hickory-Pine (PNC 101).—Conroy et al. (1982) recently investigated forage production on thinned loblolly pine plantations (Forest ML4 or 5) in the Virginia Piedmont, and developed a predictive model from their data. Forage biomass ranged from 1,500 lb/acre on open, moist sites (PC1, CC1) to 135 lb/acre in closed-canopied, xeric sites (PC4, CC4). The Assessment (PNC 101) estimates were reasonable for PC1–CC1, i.e., 1,200 lb/acre, but estimates for CC4 ranged no lower than 400 lb/acre. Unlike the situation with ponderosa pine, however, estimated production decreased in a nearly linear fashion across CC. The only problem was the large values for CC4.

Comparison With SCS Range Site Descriptions

When possible, each PNC was evaluated in comparison with SCS ecological or range sites, descriptions of which were taken from corresponding Major Land Resource Areas (MLRA). Assessment herbage and browse production estimates are listed in appendix 1 by PC and CC for each PNC. The SCS range forage production values, however, are based on climax communities, and can only be compared with Assessment estimates under CC1.

The SCS production estimates are presented in tabular form by PNC. Also included are dominant climax species, identified by acronyms or abbreviations (equivalent species names are provided in appendix 2), and estimates of annual peak forage biomass in normal years (lb/acre). Where range site production estimates consisted of three figures (production during favorable, normal, and unfavorable years), the one for normal years was used for comparison purposes. Where only two values were provided (favorable and unfavorable years), the average production between these two was used.

Nonforested Sites

Great Basin Sagebrush (PNC 32).—SCS estimates were taken from MLRA 28B (Central Nevada Basin and Range).

Range site	Dominant climax species	Normal peak biomass
		lb/acre
Sandy 8–12	Artrw, Stco, Orhy	600
Loamy 10–12	Artrw, Stth	840
Shallow Ca-loam 8–12	Ararn, Eula, Orhy	700
Steep loamy 8–12	Artrw, Stco, Orhy	400
Sandy 5–8	Atca, Eula, Orhy	300
Shallow Ca-slope 8–12	Ararn, Orhy, Stco	250
Loamy 5–8	Atco, Orhy, Stco	450
Clay basin 5–12	Atca, Agsm	1,800
Sodic loam 8–10	Artrw, Atco, Elci	400

The SCS production values tend to cluster around 450 lb/acre, which is equivalent to PC4 in the Assessment data base for PNC 32.

Only two out of nine SCS range sites produce more than 800 lb/acre. The average Assessment productivity class (PC2.5) interpolates to 1,000 lb/acre. Therefore, it appears that the Assessment estimates were somewhat inflated.

Saltbush-Greasewood (PNC 34).—SCS estimates were also taken from MLRA 28B (Central Nevada Basin and Range).

Range site	Dominant climax species	Normal peak biomass
		lb/acre
Sodic flat 5–12	Save, Atco, Spai, Dist	450
Sodic dunes 5–12	Save, Atco, Orhy	100
Alkali flat 8–10	Shar, Save, Elci	1,000
Sodic terrace 8–10	Save, Artrw, Elci	600

Except for PC4, which was a little high, comparable Assessment estimates for CC1 were reasonably close to these values.

California Steppe (PNC 41).—SCS estimates were taken from MLRAs 17 (Sacramento and San Joaquin Valley) and 18 (Sierra Nevada Foothills).

Range site	Dominant climax species	Normal peak biomass lb/acre
Coarse loamy	Brmo, Avfa, Tri., Erci	1,400
Loamy	Brmo, Avfa	1,000
Stony clay	Brmo, Avfa, Tri.	1,600
Sandy	Brmo, Avfa, Brri, Erci	700
Clayey	Brmo, Avfa, Erci, Lup.	4,200
Shallow loamy (17)	Brmo, Avfa, Erci	1,800
Shallow loamy (18)	Brmo, Avfa	800

The ranges of SCS total annual production and Assessment estimates were nearly congruent.

Grama-Galleta Steppe (PNC 47).—In Arizona, the SCS's MLRA 35 (Colorado and Green River Plateaus) contained several dozen range sites falling within the general description of PNC 47.

Range site	Dominant climax species	Normal peak biomass (Precipitation, inches) 6–10	10–14
		lb/acre	
Clay bottom	Spai, Bogr, Hija, Atca	2,500	3,000
Clay fan	Bogr, Orhy, Bohi, Atca	500	650
Clay-loam upland	Bogr, Spai, Bocu, Hija	650	650
Sandstone upland	Bohi, Hija, Bocu, Bogr	350	500
Sandy upland	Orhy, Stco, Sihy, Arfi	500	525
Saline bottom	Spai, Hija, Poab, Atca	1,100	—
Shale upland	Spai, Hija, Atco	150	—
Breaks	Pofe, Stco, Orhy, P-J	—	800
Loamy bottom	Agsm, Pofe, Orhy, Bogr, Atca	1,600	1,700
Cinder hills	Bocu, Bohi, Bogr, Hija	—	800

Assessment estimates were much lower than SCS observations for PNC 47. The maximum production shown (PC1, CC1, ML = D) of 600 lb/acre did not reach the median production from all SCS sites of 650 lb/acre.

Sagebrush Steppe (PNC 49).—Within five MLRAs (10, Upper Snake River Lava Plains; 11, Snake River Plains; 12, Lost River Valley; 13, Eastern Idaho Plateau; 25, Owyhee High Plateau of Idaho) the SCS has defined over 100 range sites that fall within PNC 49. Total production ranged from 125 (Very Shallow 8–16 inches precipitation, Arri/Pose) to 2600 lb/acre (Loamy 22" inches precipitation +, Artrv/Brca, Feid). The median production for all site was 700 lb/acre.

The Assessment estimates (CC1) for PNC 49 were adequate for PC1 and PC2; however, they appeared to be high for PC3 and PC4 (appendix 1.5). Nearly 75% of the SCS range sites produced less 1,000 lb/acre (CC3), while one-quarter of them produced less than 500 lb/acre (CC4). Apparently, more sensitivity was required in the range of 300–800 lb/acre and less in the range of 1,000–1,500 lb/acre.

Grama-Tabosa Shrubsteppe (PNC 52).—SCS range sites were taken from MLRA 41 (Southeastern Arizona Basin and Range).

Range site	Dominant climax species	Normal peak biomass lb/acre
Loamy upland 16–20	Bocu, Bogr, Opunt., Yucca	1,350
Limy slopes 16–20	Boer, Bocu, Yuba	1,200
Breaks 7–12	Himu, Ladi, Atco	150
Clay bottom 7–12	Himu, Anba	1,000
Clay upland 7–12	Himu, Boer, Opunt.	600
Granitic hills 7–12	Bogr, Boer, Yucca	700
Limy slopes 7–12	Boer, Himu, Latr	350
Limy upland 7–12	Mupo, Boer, Latr	250
Loamy bottom 7–12	Spwr, Himu, Bocu	2,000
Loamy upland 7–12	Boer, Himu, Bocu	750
Saline bottom 7–12	Spai, Himu, Atca	700
Basalt hills 12–16	Boer, Bocu, Agave	525
Clay upland 12–16	Himu, Bocu	950

Potential production (CC1) extended from 150 lb/acre on dry breaks to 2,000 lb/acre on loamy bottoms. The Assessment estimates in this case were tightly bunched at the low end of the scale, and apparently did not reflect the fairly wide range in SCS production values for PNC 52.

Trans-Pecos Shrub Savanna (PNC 53).—SCS range site descriptions were taken from MRLA 42 (Southern Desertic Basins, Plains, and Mountains) in Texas.

Range site	Dominant climax species	Normal peak biomass lb/acre
Clay flat	Himu, Paob, Spai	550
Draw	Mupo, Bocu, numerous shrubs	850
Gravelly	Latr, Boer, Mupo	250
Gravelly outwash	Acacia, Boer, Bocu	350
Gyp	Atca, Boer, Spai	300
Limestone hill and mountain	Krame., Boer	550
Loamy	Bogr, Boer, Scbr	800
Loamy bottomland	Spgi, Spai, Flce	1,500
Salty	Spai, Atca	700
Sand hill	Sporo., Atca, Latr	300

The Assessment estimates were weighted too high according to the SCS information. For example, "normal"

production for all but one of the above range sites fall below the Assessment estimate for PC3, and nearly half are less than the estimate for PC4.

Mesquite-Acacia Savanna (PNC 54).—According to maps of PNCs (USDA Forest Service 1978) and MLRAs (USDA SCS 1981), PNC 54 extends from the Rio Grande Plain into the Edwards Plateau. The assumption was made that the Rio Grande Plain more closely represented a mesquite-acacia savanna, and it was selected (MLRA 83) for this comparison.

Range site	Dominant climax species	Normal peak biomass
		lb/acre
Clay flat	Trich., Paob, Andro.	4,200
Clay loam	Trich., Andro., Prju	3,500
Deep sand	Ansc, Quer.	3,200
Loamy sand	Andro., Pasp., Quvi, Prju	3,500
Sandstone hills	Ansc, Sonu, Quer.	2,500
Sandy	Anli, Sonu, Prju	3,500
Shallow	Bocu, Cepa	2,200
Shallow ridge	Bocu, Ansc, Coleo.	1,800
Tight sandy loam	Trich., Ansc, Prju	3,000

In examining CC1 of PNC 54, it appears that its range of biomass is both too narrow and shifted somewhat to the low side. All of the range sites except one produce more than the 2,000 lb/acre stipulated in PC2. Peak biomass for two-thirds of the SCS range sites exceed the Assessment maximum in PC1-CC1.

Foothills Prairie (PNC 56).—The SCS range site descriptions were taken from a series entitled Foothills and Mountains. Although not referenced to a MLRA, they undoubtably fit MRLA 46 (Northern Rocky Mountain Foothills).

Range site	Dominant climax species	Normal peak biomass (Precipitation, inches)	
		6–10	10–14
		lb/acre	
Very Shallow	Agsp, Stco, Erio	600	800
Clayey	Agsp, Agsm, Pofr	1,300	2,000
Silty	Agsp, Fesc, Artr	1,500	2,200
Overflow	Elci, Agsm, Prun	2,500	3,300
Sandy	Agsp, Stco, Rhtr	1,600	2,300
Thin hilly	Agsp, Agsm, Artr	1,100	1,700
Sands	Calo, Orhy, Stco	2,000	—
Saline lowland	Spai, Elci, Atga	2,800	—

The Assessment data base effectively captured the lower (PC4) end of the forage production scale; and it can be considered reasonably accurate at the upper end (PC1) if the sites receiving additional runoff are not considered. Given the rarity of these sites, such an omission was probably not important.

Grama-Needlegrass-Wheatgrass (PNC 57).—PNC 57 spans two major MLRAs (52, Brown Glaciated Plain; 58, Northern High Plain). Fortunately, similarly named sites in both have the same production values.

Range site	Dominant climax species	Normal peak biomass
		lb/acre
Dense clay	Agsm, Stvi	900
Shallow	Agsp, Agsm, Bogr	900
Very shallow	Agro., Stco, Bogr	600
Saline upland	Spai, Agsm	500
Shale	Agsm, Spai, Dist	400
Clayey	Agsm, Stvi, Agsp	1,300
Silty	Agsp, Agsm, Stco	1,500
Sands	Spai, Orhy, Stco	2,000
Overflow	Elci, Agsm, Stvi	2,500

As with the foothills prairie (PNC 56), Assessment production estimates adequately span the appropriate SCS figures for PNC 57 only if those sites receiving additional water are not included.

Grama-Buffalo Grass (PNC 58).—PNC 58, one of the more widespread of all PNCs, encompasses the high plains from southeastern Wyoming to west Texas. Two major MLRAs were used, one in Colorado (67, Central High Plains) and the other in Texas (77, Southern High Plains). Those listed below are from MRLA 67; those from MRLA 77 fell in the same production range.

Range site	Dominant climax species	Normal peak biomass
		lb/acre
Loamy slopes	Bogr, Agsm	1,000
Siltstone plains	Bogr, Agsm, Atca	1,400
Sandy plains	Bogr, Calo, Bocu	1,800
Shaly plains	Spai, Bogr, Bocu	550
Plains swale	Agsm, Buda, Bogr	1,200
Salt flat	Spai, Bogr, Hija	1,000
Shallow siltstone	Bogr, Agsm, Eula	800
Sandstone breaks	Bogr, Bocu	750
Overflow	Pavi, Agsm, Bogr	2,500

Unlike the previous two PNCs, Assessment estimates for PNC 58 did not cover all SCS range sites, even when those receiving supplemental water, such as subirrigated and overflow sites, were excluded. The Assessment estimates were lower for all PCs.

Wheatgrass-Needlegrass (PNC 59).—SCS range site descriptions were taken from two sets of MLRAs in South Dakota: the Prairie Shale Plains and Badlands (60A) and, to its east, the more mesic Northern Rolling Pierre Shale Plains (63A).

Range site	Dominant climax species	Normal peak biomass (MLRA) 60	63
		lb/acre	
Loamy overflow	Ange, Pavi, Agsm, Rosa	2,600	3,200
Loamy terrace	Agsm, Stvi, Calo	2,300	2,700
Sands	Ansc, Anha, Calo, Stco	2,000	2,400
Silty	Agsm, Stvi, Stco	1,850	2,250
Clayey	Agsm, Stvi, Buda	1,750	2,050
Thin upland	Stco, Bogr, Cafi, Agsm	1,400	1,750
Shallow to gravel	Stco, Bogr, Cafi	1,150	1,450
Thin claypan	Bogr, Buda, Agsm	850	1,050
Saline upland	Agsm, Dist, Atga	750	—

The Assessment estimates fit these SCS averages reasonably well; however, it appears that the fit might have been better if they were shifted upward as a group by a few hundred pounds per acre.

Wheatgrass-Bluestem-Needlegrass (PNC 60).—SCS range site descriptions were taken from MLRA 55 (Black Glaciated Plains), found in east-central North Dakota and South Dakota.

Range site	Dominant climax species	Normal peak biomass lb/acre
Subirrigated	Ange, Pavi, Sonu	5,100
Overflow	Ange, Stvi, Agsm	3,850
Saline lowland	Agsm, Dist, Puai	3,750
Sands	Anha, Calo, Ansc, Stco	2,800
Silty	Stvi, Agsm, Stco, Ansc	2,800
Clayey	Agsm, Stvi, Ansc	2,600
Thin upland	Ansc, Stvi, Stco	2,350
Claypan	Agsm, Stvi, Bogr	2,000
Thin claypan	Agsm, Bogr, Buda	1,450
Very shallow	Stco, Bogr, Cafi	1,450

A comparison of the above measures with the Assessment leads to the same conclusion reached several times before; i.e., the two are reasonably congruous only if those sites receiving supplemental water through runoff or subirrigation are neglected.

Bluestem-Grama Prairie (PNC 62).—The SCS range site descriptions were taken from the 20- to 24-inch precipitation zone in west-central Kansas. They are not yet associated with MLRAs; however, if they were, MLRA 73 (Rolling Plains and Breaks) would probably apply best.

Range site	Dominant climax species	Normal peak biomass lb/acre
Blue shale	Bocu, Agsm, Ange	1,800
Chalk flats	Ansc, Bocu	3,000
Clay lowland	Pavi, Ange, Sonu	4,500
Clay upland	Bocu, Agsm, Spas	2,000
Gravelly hills	Ange, Anha, Bocu	1,600
Limy upland	Ange, Bocu, Ansc	2,450
Loamy terrace	Pavi, Ange, Sonu	3,500
Saline subirrigated	Spai, Pavi, Sonu	6,500
Sandy	Anha, Ange, Ansc	2,200
Loamy lowland	Ange, Sonu, Ansc	4,800
Red shale	Ange, Ansc, Bocu	1,200

Although the Assessment data base adequately covered the unproductive end of range sites (PC4), it was somewhat low for productive ones. In fact, nearly half of the SCS range sites in good to excellent condition produce more than the Assessment estimate for PC1 (3,000 lb/acre).

Bluestem Prairie (PNC 66).—The SCS sites for PNC 66 were taken from MLRA 76 (Bluestem Hills) in east-central Kansas.

Range site	Dominant climax species	Normal peak biomass lb/acre
Clay lowland	Sppe, Pavi, Ange	5,000–7,500[2]
Clay upland	Ange, Ansc, Sonu, Pavi	2,500–2,500
Claypan	Ange, Ansc, Bocu	2,000–3,000
Flint ridge	Ansc, Ange, Bocu	1,500–2,200
Loamy lowland	Ange, Sonu, Pavi	6,000–8,000
Loamy upland	Ange, Ansc, Sonu, Pavi	3,500–5,000
Shallow limy	Ansc, Bocu	2,000–2,500

The Assessment estimates did an excellent job of covering both the range and distribution of SCS range sites examined.

Nebraska Sandhills (PNC 67).—SCS range site information was taken from MLRA 65 (Nebraska Sandhills). Because of its unique physiography and vegetation, the correlation between Küchler PNC and MLRA is nowhere higher than for the Nebraska sandhills.

[2]Use of fire and plant vigor influence production among sampling areas in the same ecological condition. For this study, the higher values would reflect a more intensive level of range management (ML = D)

Range site	Dominant climax species	Normal peak biomass (Precipitation, inches) 6–10	10–14
		lb/acre	
Subirrigated	Ange, Sonu, Ansc, Sppe	4,400	4,900
Sandy lowland	Ansc, Anha, Calo, Pavi	2,400	2,900
Savanna	Ansc, Stco, Calo, Pipo	2,000	—
Sandy	Calo, Anha, Ansc, Stco	2,400	2,900
Choppy sands	Anha, Calo, Ansc, Pavi	2,200	2,700
Sands	Anha, Calo, Ansc, Pavi	2,300	2,800
Shallow to gravel	Bogr, Anha, Stco, Spcr	1,000	1,300

Except for those sites that either receive supplemental water or are excessively xeric, total production varies between 2,000 and 3,000 lb/acre. The Assessment estimates did a reasonable job of depicting these figures. It could be argued that PC1 underestimated the most productive sites, and PC2 overestimated the top of the 2,000–3,000 lb/acre range; however, such inaccuracies are insignificant at a national level of integration.

Cross Timbers (PNC 75).—SCS range site information for PNC 75 were obtained from MLRA 84 (Cross Timbers) in Oklahoma and Texas. The dominant species, listed below, do not contain woody species prevalent in the Cross Timbers, which usually present a savanna-like physiognomy. Among the woody species mentioned in the range site descriptions as being common in the Cross Timbers region are *Quercus marilandica*, *Q. stellata*, *Rhus* spp., *Carya illinvensis*, and *Ulmus* spp.

Range site	Dominant climax species	Normal peak biomass *lb/acre*
Deep sand savanna	Anha, Ansc	3,000
Deep sand savannah breaks	Sonu, Ange	2,600
Eroded clay	Bocu, Bogr	1,500
Eroded sandy savanna	Ansc, Sonu	2,100
Eroded shallow savanna	Ansc, Sonu, Pavi	1,400
Heavy bottomland	Pavi, Sppe, Ange	5,500
Loamy bottomland	Ange, Pavi, Sonu	6,500
Sandy bottomland	Anha, Sonu, Ansc	2,900
Sandstone hills	Ansc, Sonu, Ange	2,800
Sandy	Ansc, Sonu, Pavi	3,700
Sandy savanna	Anha, Ansc	4,000
Savannah breaks	Ange, Ansc, Sonu	1,200
Shallow savanna	Ansc, Anha, Bocu	2,100
Subirrigated	Pavi, Ange, Sonu	9,000

The Assessment data base came well short of correctly estimating peak biomass on the most productive sites (PC1), even if the subirrigated site was not considered. In addition, its lowest estimates (PC4) were too high for several of the eroded SCS range sites. In other words, actual Cross Timbers understory production extends below the Assessment estimates at the low end of the range and above it at the high end.

Mesquite-Buffalo Grass (PNC 76).—For PNC 76, SCS range site information was taken primarily from MLRA 78, the Central Rolling Red Plains of Texas. Additional production figures were obtained from MLRA 80, the Texas Central Prairie, which also is included in PNC 76; hence, the range in biomass for some range sites shown below.

Range site	Dominant climax species	Normal peak biomass *lb/acre*
Clay loam	Bogr, Buda, Himu	1,500
Clay flat	Himu, Spai, Buda	1,000–1,600
Claypan prairie	Paob, Bocu, Buda	2,100
Draw	Bocu, Paob, Agsm	3,200
Gravelly	Bocu, Ansc, Bohi	1,000–1,500
Gyp	Bocu, Ansc, Buda	600
Loamy bottomland	Sonu, Pavi, Bocu	2,700–5,500
Loamy prairie	Bogr, Buda, Bocu	1,800–2,200
Loamy sand	Anha, Ansc, Bocu	2,300–4,500
Rough breaks	Bocu, Ansc, Bohi	600
Sandy loam	Bogr, Bocu, Paob	2,200–4,200
Shallow clay	Bogr, Bocu, Buda, Himu	1,100–1,500
Very shallow	Bocu, Ansc, Buda	800

Numerous woody species were recorded by the SCS as being associated with these range sites; however, their cover seldom exceeded 5% under excellent condition. Among species prevalent to the Rolling Red Plains are *Ephedra* spp., *Celtis* spp., *Juniperus* spp., *Lycium* spp., *Condalia lycioides*, and *Acacia greggii*. Mesquite (*Prosopis* spp.) is normally not a climax constituent, but increases greatly during retrogression, according to the SCS range site descriptions.

The Assessment estimates for PNC 76 encompassed all range sites except the most productive (loamy bottomland) and the least productive (gyp, rough breaks, very shallow). The SCS range sites in PNC 76 showed comparatively wide variation in production depending mostly upon precipitation, and the ID-team estimates could have been expanded in range to accommodate these extremes.

Juniper-Oak Savanna (PNC 77).—The juniper-oak savanna is superimposed mostly on the Edwards Plateau region of Texas (MLRA 81). Like the previous PNC, mesquite-buffalo grass (PNC 76), the Edwards Plateau is characterized by a savanna composed of numerous tree species that rarely exceed 5% in total crown cover. Many of the woody species are common to both PNCs. As in PNC 76, mesquite only becomes dominant during retrogression.

Range site	Dominant climax species	Normal peak biomass (Precipitation, inches) 6–10	10–14
		lb/acre	
Clay loam	Bocu, Andro., Buda	2,700	—
Deep redland	Ansc, Sonu, Bocu	—	3,800
Flagstone	Bocu, Ledu	800	—
Loamy bottomland	Sonu, Ansc, Bocu, Ange	3,200	4,500
Low stony hill	Andro., Bocu, Ledu	1,800	2,300
Shallow	Bocu, Ansc, Buda	1,900	2,400
Shallow ridge	Bocu, Ledu, Sema	1,500	—
Steep rocky	Ansc, Bocu, Ledu	1,300	—
Steep adobe	Ansc, Sonu, Bocu	—	2,000

Taken collectively, the Assessment estimates for PNC 77 were relatively high. In fact, more than half of the SCS range sites fall below the production estimate for PC4, some by 50% or more. Alternatively, none of the range sites reach the magnitude of PC2, let alone approaching that for PC1.

Mountain Meadow (PNC 107).—Mountain meadows are not associated with any specific MLRAs, but are interspersed throughout the western cordilleran forests. As such, SCS descriptions of most meadow sites can be found in MLRAs comprising the Rocky Mountain Range and Forest Land Resource Region (USDA SCS 1981). For this evaluation, meadow sites have been taken from Idaho and Colorado.

Range site	Dominant climax species	Normal peak biomass lb/acre
Idaho		
Semiwet meadow, north	Deca, Carex Agtr	3,800
Semiwet meadow, south	Carex, Agtr, Deca	2,250
Semiwet saline meadow	Spai, Poju, Dist	1,750
Wet meadow, north	Carex, Deca, Junc.	6,000
Wet meadow, south	Carex, Junc.	5,000
Colorado		
Swale meadow	Agsm, Cane, Elci	2,000
Salt meadow	Spai, Dist, Agsm	1,500
Wet meadow	Deca, Cane, Agtr	2,000[3]

[3]Some SCS range conservationists believe this figure should be higher, perhaps 3500–4000 lb/acre. (Personal communication with Noel Wellborn, SCS-Colorado.)

For the most part, the Assessment estimates adequately reflected SCS range site production figures. They could have been made more accurate by raising PC1 by 2,000 lb/acre and PC4 by 500 lb/acre.

Forested Sites

SCS site descriptions are generally only available for western PNCs, and of these, some include no understory production information. For example, Oregon has developed range site descriptions for associations in the cedar-hemlock zone (PNC 2); however, they contain blanks in the sections referring to both understory production and suggested initial stocking rates. Those PNCs for which information is available follow.

Western Ponderosa Forest (PNC 10).—Although PNC 10 is widespread throughout Washington, Oregon, Idaho, and western Montana, few range site descriptions that include production information have been written for it. The following were taken from Washington (MLRA 6, Cascade Mountains Eastern Slope; MLRA 9, Palouse and Nez Perce Prairies).

Range site	Dominant climax species	Normal peak biomass (Canopy cover, % 0–20	20–40	40+
		lb/acre		
Loamy, ponderosa pine, Idaho fescue	Feid, Agsp, Basa	1,200	900	300
Very stony, shallow, ponderosa pine, bluebunch wheatgrass	Agsp, Pose, Feid, Syal	600	400	150
Loamy, 20–45, droughty	Cage, Caru, Lup., Syal	—	110	—

The Assessment estimates were inadequate to express the range of understory production shown in only three SCS range site descriptions.

Although a constant figure of 800 lb/acre across all PCs may have approximated the average of all sites, it certainly did not mimic their variation. In addition, two of the SCS range sites relate understory biomass to overstory canopy (i.e., CC); they depict an attenuation from CC1 to CC4 of about 4:1, with most of the decrease between CC3 and CC4. Contradictorily, the Assessment estimates show an astounding 8:1 reduction between CC1 and CC2, followed by a gradual increase in understory production in CC3 and CC4. There is no logical explanation for the conceptual model of understory production represented in the Assessment estimates.

Douglas-fir Forest (PNC 11).—SCS site descriptions of Douglas-fir associations are only available from Idaho. As shown with ponderosa pine, few SCS state offices have developed descriptions, including understory production information, for the more mesic coniferous forest zones.

Range site	Dominant climax species	Normal peak biomass (50% canopy) *lb/acre*
Douglas-fir, stony 22	Caru, Feid, Artrv	1,000
Douglas-fir, mountain snowberry, 22+	Agsp, Syor, Artrv	900

The SCS information is insufficient to judge the scope of the Assessment for PNC 11. The values shown above, assuming 50% canopy cover is equivalent to CC3, fall nicely in the range of appropriate Assessment estimates; however, that is the only conclusion possible.

Pinyon-Juniper (PNC 21).—The SCS range site information was taken from two states, Utah and New Mexico. The sites represent six MLRAs in Utah and two other MLRAs in New Mexico. Obviously, pinyon-juniper is widely distributed both geographically and ecologically within the intermountain and southern Rocky Mountain regions.

Range site	Dominant climax species	Normal peak biomass *lb/acre*
Utah		
Upland shallow loam	Agsp, Orhy, Juos	1,300
Upland shallow loam (summer ppt)	Carex, Orhy, Bogr, Juos	750
Upland stony loam	Agsp, Pofe, Juos	1,000
Upland stony loam (summer ppt)	Orhy, Pone, Juos Pied	1,600
Shallow upland stony sand	Stco, Bogr, Spcr, Juos, Pied	850
Upland shallow hardpan	Orhy, Stco, Juos, Pied	650
Semidesert shallow loam (summer ppt)	Muem, Pied, Juos	325
New Mexico		
Sand plains	Orhy, Sporo., Jumo, Peid	800
Shallow savanna	Stco, Bogr, Hija, Jusc, Pied	600
Hills	Bogr, Ansc, Bocu, P–J	1,100
Shallow sandstone	Bogr, Bocu, P–J	750
Breaks	Bocu, Ansc, P–J	800
Shallow limy savanna	Ansc, Bocu, P–J	700
Deep sand savanna	Andro., Calo, P–J	1,000

The Assessment estimates adequately covered most of the SCS range site production figures. If the estimate for CC1 (1,000 lb/acre) were increased by 50%, coverage would have been more than adequate.

California Oakwoods (PNC 26).—The SCS estimates were obtained from MLRA 15, Central California Coast Range; and 18, Sierra Nevada Foothills.

Range site	Dominant climax species	Normal peak biomass *lb/acre*
Blue oak-white oak	Qudo, Qulo, Brmo, Avfa	
Open canopy (CC1)		2,000
Medium canopy (CC3)		1,200
Dense canopy (CC4)		600
Gravelly loam (ML = D)	Brmo, Avfa	1,200
Very stony shallow loam	Qudo, Brmo, Feme	400
Very gravelly loamy	Brmo, Avfa, Erci, Qudo	900
Claypan	Brmo, Erci, Qudo	2,100

If the SCS production figures are accurate, the Assessment estimates contained two serious shortcomings. First, they did not mimic the decreased production associated with overstory canopy closure (i.e., increasing CC). Second, they came nowhere near approaching the range in production (400–2,100 lb/acre) associated with CC1.

DISCUSSION

Herbage and browse production estimates for major rangeland PNCs in the 1980 Assessment varied in accuracy, both overall and in relation to changes in PC and CC. The following discussion attempts to synthesize results from each of the evaluation techniques (intrinsic evaluation and comparisons with both research information and SCS range sites) for those PNCs that appeared to have deficiencies.

One aspect concerning the assumptions made by the Assessment ID teams became important during the synthesis of results reported above. Küchler's (1964) PNCs were mapped on a scale of 1:7,500,000. At this scale, a map distance of only 1 mm would amount to 7.5 km (4.7 miles) on the ground. Therefore, Küchler could not include the mosaic of natural associations that are present across the landscape within any given PNC, but mapped only generalized vegetation. It is probably safe to assume that the extent of Küchler's PNCs roughly coincide with the geographic range of their respective dominant species as such species comprise climatic climax communities, i.e., are found on zonal soils (Personal Communication, Robert G. Bailey, USDA Forest Service, Fort Collins, Colo.).

Given this situation, the ID teams had to decide whether or not to include resource outputs from all associations making up a "significant" proportion of the land area within a given PNC, even if they are not normally a climatic component of the PNC. Their decision would have consitituted a crucial assumption built into their inituitive models. For example, on the short-grass plains (PNC 58), communities more typical of the mixed-grass and tall grass prairie occur on bottomland sites, sometimes over extensive areas. Obviously, such com-

munities are capable of producing much more herbage than any site dominated by blue grama and buffalo grass, the characteristic species of PNC 58. Therefore, the assumption to include these communities would greatly affect the Assessment estimates for PC1 within several PNCs.

Evidently, the intent of the ID teams was to view each PNC as a homogeneous abstraction (personal communication, Richard Ross, Superior National Forest, Duluth, Minn.). Whether or not individual ID teams followed such a strategy is unclear, given the range of production estimates for some PNCs and the lack of data for "abstract" communities.

Sagebrush-Grass Region (PNC 32 and 49).—All three methods provided results consistent with each other. Assessment production estimates for the 140 to 170 million acres (Tisdale and Hironaka 1981) of sagebrush-grass in the western United States were too high, primarily because of the conceptual model of production in relation to CC used by the ID team(s). First and most important, Assessment production estimates were unaffected by decreasing CC, so areas in less than excellent range condition would therefore be shown to have the same production as those in excellent condition (table 8). Although no one knows how much sagebrush-grass rangeland is in depleted condition, there is some indication that three-fourths of it is rated in fair condition or worse and about one-third may be in poor condition (USDA BLM 1977). Even if these figures are exaggerated, the proportions must still be significantly large.

The second shortcoming of the Assessment estimates lies in their overestimation of production on sites with lower production potential (PC3, PC4). Most of the sagebrush-steppe (PNC 49) is characterized by sagebrush-grass communities dominated by *Artemisia tridentata* spp. *wyomingensis*. These communities normally produce substantially less than the Assessment estimates provided under PC3 and PC4, as explained previously in this paper.

Grama-Galleta Steppe (PNC 47).—The Assessment estimates for PNC 47 constituted a paradox. According to the SCS range site descriptions, they greatly underestimated production on ranges in good condition (CC1). However, because the conceptual model developed by the ID team called for constant production across all CCs within a given PC, it is quite possible that Assessment estimates for the lower CCs were reasonably accurate. Unfortunately, little, if any, research has been published on total production for this PNC. Initially, the Assessment estimates could be improved by progressively raising the values in the higher CCs by fourfold to fivefold.

Grama-Tabosa Shrubsteppe (PNC 52).—The same general comments made concerning PNC 47 apply to PNC 52; i.e., the conceptual model of production versus CC was constant, and the Assessment estimates underestimated production at the higher CCs. The remedy, changing the conceptual model, remains the same.

Trans-Pecos Shrub Savanna (PNC 53).—The Assessment estimates apparently were consistently high across the board. They were relatively precise in relation to each other, but inaccurate. The conceptual model could be changed by eliminating or greatly lowering the intercept (α_0) in order to remedy this discrepancy. Other more subtle changes to the model may also be useful, depending upon the availability of future research information.

Mesquite-Acacia Savanna (PNC 54).—The Assessment estimates for PNC 54 were, in contrast to PNC 53, consistently low across the board. The conceptual model expressed in the ID-team estimates contained an excessive number of interaction effects for the available information, and its intercept (PC4–CC4) appeared too low. A simpler model reflecting the wide range in potential production would be both more accurate and easier to interpret.

Grama-Buffalo Grass (PNC 58).—Information about PNC 58 illustrates the problem of which associations or range sites to include in the evaluation, discussed earlier in this section. According to comparisons with research data available from shortgrass sites, the Assessment estimates overestimated actual production. On the other hand, when compared to descriptions of all important SCS range sites comprising PNC 58, the Assessment estimates fell well short. A solution to this paradox, and the resultant improvement of any Assessment estimates for PNC 58, can only come after the underlying assumption is made explicit, one way or the other. Given the constraint of accounting for land area by PNCs as they are mapped, it appears that the Assessment estimates actually underestimate herbage production at all PCs.

Cross Timbers (PNC 75).—Inadequacies in the Assessment estimates of PNC 75 were discussed in the section on comparisons with SCS range site descriptions. The lack of coverage may have been due in part to ID-team unfamiliarity with characteristics of the Cross Timbers. Unlike major PNCs of the Great Plains, the Cross Timbers has received less research or publicity since the early work of Dyksterhuis (1948). Such a situation points out the importance of adequate background information if intuitive models are to be effective. The problem may have been a causal factor in discrepancies between Assessment estimates and SCS range site descriptions for other PNCs restricted primarily to the southern Plains, either to a small (PNC 76) or larger (PNC 77) extent.

Forested PNCs (2, 5, 10, 11, 14, 26, 91, 95, 101, 102, 103).—Because of the lack of research data and range site descriptions for forested PNCs, a synthetical evaluation of Assessment estimates is infeasible. The only other evaluation possible, that of examining the Assessment estimates intrinsically, has already been completed in this paper.

CONCLUSIONS

Intuitive models, like other models used in ecology and natural resource management, are intrinsically transient in nature. They are developed for a specific purpose, but seldom are used by others who may have

similar but (always) different needs. Some of the reasons for the non-use of existing models has to do with their applicability to related problems for which they were not designed. Just as important, however, is the idea that much of the usefulness derived from modeling comes from activities associated with model development (Innis 1972).

For RPA Assessments, the problem is not one of different users, but of the same user over time. Consequently, unless legislation or regulations pertaining to recurring Assessments are amended, the users' needs are unchanged, and one of the major reasons for not using existing models is eliminated.

Looking into the future 10 to 15 years, one sees little likelihood of replacing the intuitive models of herbage and browse production used in the 1980 Assessment with more quantitative mathematical models. The major impediment to developing such regional level models is the lack of a quantititive theoretical framework in ecology (Joyce et al. 1983).

Given the continued raison d'etre of RPA Assessments, the lack of a quantitative approach towards providing herbage and browse production coefficients at the regional level, and the overall accuracy of ID-team estimates in the 1980 Assessment, one can conclude that such estimates can provide the framework for intuitive primary models in the next Assessment. Nonetheless, it seems reasonable to suggest that some parts of the Assessment data set are sufficiently inaccurate to require changing. If such an undertaking is attempted, a procedure like that used in this paper should be adopted. In addition, future ID-teams would be well advised to more adequately record assumptions made that affect their estimates of resource outputs, both for their own edification and internal consistency, and as an aid in appraising the outputs of their intuitive models.

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APPENDIX 1

Herbage-Browse Production Estimates (lb/acre) by Productivity Class, Condition Class, and Management Level (ML) for Selected PNCs in the 1980 Assessment Range Data Base

NONFORESTED SITES

PNC 32: Great Basin Sagebrush
Owner – 2
State – NV

Condition Class	Productivity Class 1	2	3	4
1	1500	1200	800	400
	1500	1200	800	400
2	1500	1200	800	400
	1500	1200	800	400 (D)
3	1500	1200		400
	1500	1200	800	400 (D)
4	1500	1200		400
	1500	1200	800	400 (D)

ML A
ML C (D)

PNC 34: Saltbush-Greasewood
Owner – 2
State – UT

Condition Class	Productivity Class 1	2	3	4
1	1000	750	500	250
	1000	750	500	250
2	900	650	400	150
	900	650	400	150
3	800	550	300	50
	800	550	300	50
4	750	500	250	0
	740	500	250	0

ML A
ML C

PNC 41: California Steppe (Annual Grassland)
Owner – 4
State – CA

Condition Class	Productivity Class 1	2	3	4
1	3200	2800	1600	800
	4500	3700	1800	900
2	3200	2800	1600	800
	4500	3700	1800	900
3	3200	2800	1600	800
	4500	3700	1800	900
4	3200	2800	1600	800
	4500	3700	1800	900

ML C
ML D

PNC 47: Grama-Galleta Steppe
Owner – 4
State – NM

		Productivity Class			
		1	2	3	4
Condition Class	1	500 600	400 500	300 300	200 200
	2	500 600	400 500	300 300	200 200
	3	500 600	400 500	300 300	200 200
	4	500 500	400 500	300 300	200 200
ML B ML D					

PNC 49: Sagebrush Steppe
Owner – 2
State – ID

		Productivity Class			
		1	2	3	4
Condition Class	1	2000 2500	1500 1800	1000 1200	500
	2	2000 2500	1500 1800	1000 1200	500
	3	2000 2200	1500 1600	1000 1200	500
	4	2000 2200	1500 1600	1000 1100	500
ML C ML D					

PNC 52: Grama-Tabosa Shrubsteppe
Owner – 4
State – NM

		Productivity Class			
		1	2	3	4
Condition Class	1	500	300	200	100
	2	500	300	200	100
	3	500	300	200	100
	4	500	300	200	100
ML B, C					

PNC 53: Trans-Pecos Shrub Savanna
Owner – 4
State – TX

		Productivity Class			
		1	2	3	4
	1	1700 2100		900 1200	500 500
	2	1600 2000		800 1200	400 400

Condition Class					
	3	1400		700	300
		2000		1200	300
	4	1200		600	200
		2000		1200	200

ML C
ML D

PNC 54: Mesquite-Acacia Savanna
Owner – 4
State – TX

		Productivity Class			
		1	2	3	4
	1	2500	2000	1500	1000
		2500	2400	1800	1200
	2	1900	1500	1100	700
		2400	1900	1400	900
Condition Class	3	1200	900	700	500
		1600	1200	1000	700
	4	500	400	300	200
		700	600	400	300

ML B
ML E

PNC 56: Foothills Prairie
Owner – 4
State – MT

		Productivity Class			
		1	2	3	4
	1	2000	1400	1000	500
					400
	2	1500	1100	800	400
Condition Class					300
	3	1000	800	500	300
	4	500	400	300	200
		500	400	300	200

ML A
ML C

PNC 57: Grama-Needlegrass-Wheatgrass
Owner – 4
State – MT

		Productivity Class			
		1	2	3	4
	1	1600	1200	800	400
		1900	1400	1000	500
	2	1200	900	600	300
		1400	1100	800	
Condition Class	3	800	600	400	200
		900	700		
	4	400	300	200	100

ML B, C
ML D

PNC 58: Grama-Buffalo Grass
Owner – 2
State – CO

		Productivity Class			
		1	2	3	4
Condition Class	1	1000	800	600	400
	2	800	600	500	300
	3	600	500	300	200
	4	400	300	200	100
ML C					

PNC 59: Wheatgrass-Needlegrass
Owner – 4
State– UT

		Productivity Class			
		1	2	3	4
Condition Class	1	2500	1700	1000	600
		3700	2500	1500	900
	2	1700	1300	800	400
		2500	1900	1200	600
	3	1000	800	500	200
		1500	1200	700	300
	4	600	400	200	100
		900	500	300	100
ML C					
ML D					

PNC 60: Wheatgrass-Bluestem-Needlegrass
Owner – 4
State – ND

		Productivity Class			
		1	2	3	4
Condition Class	1	3000	2400	1800	1200
		3100	2500	1800	1200
	2	2500	200	1500	1000
		2600	2100	1500	1000
	3	2000	1600	1200	800
		2200	1800	1300	900
	4	1500	1200	900	600
		1600	1300	1000	700
ML C					
MLD					

PNC 62: Bluestem-Grama Prairie
Owner – 4
State – KS

		Productivity Class			
		1	2	3	4
	1	3000	2400	1800	1200
		3000	2400	1800	1200
	2	2700	2200	1600	1100
		2700	2200	1600	1100

Condition Class					
	3	2300	1900	1400	900
		2800	2300	1700	1100
	4	2000	1600	1200	800
		2400	1900	1400	1000

ML A, C
ML D

PNC 66: Bluestem Prairie
Owner – 4
State – OK

		Productivity Class			
		1	2	3	4
Condition Class	1	6800	4400	3000	1700
		7400	5000	3500	2300
	2	6700	4300	2800	1600
		7200	4800	3300	2100
	3	5500	3800	2600	1400
		6800	4400	3100	1900
	4	5000	3500	2200	1000
		6800	4400	3100	1900

ML C
ML D

PNC 67: Nebraska Sandhills
Owner – 4
State – NE

		Productivity Class			
		1	2	3	4
Condition Class	1	4300	3200	2100	1000
	2	4000	3100	2000	800
	3	3900	2800	1700	600
	4	3900	2800	1700	600

ML C

PNC 75: Cross Timbers
Owner – 4
State – OK

		Productivity Class			
		1	2	3	4
Condition Class	1	4800	3900	3000	2100
	2	4000	3200	2500	1700
	3	3200	2500	2000	1300
	4	2400	1800	1500	900

ML C

PNC 76: Mesquite-Buffalo Grass
Owner – 4
State – TX

		Productivity Class			
		1	2	3	4
	1	3500	2700	2000	1200
		4200	3200	2000	1200

Condition Class		1	2	3	4
	2	3400	2600	1900	1100
		4100	2600	1900	1100
	3	3200	2500	1700	1000
		3800	3000	1700	1000
	4	3000	2300	1500	800
		3600	2800	1500	800

ML B
ML D

PNC 77: Juniper-Oak Savanna
Owner – 4
State – TX

		Productivity Class			
		1	2	3	4
Condition Class	1	6000	4800	3600	2400
	2	4800	3600	2400	1800
	3	3600	2400	1800	1200
	4	4800	2400	1800	1200

ML D

PNC 107: Mountain Meadow
Owner – 1
State – MT

		Productivity Class			
		1	2	3	4
Condition Class	1	4000	3000	2000	1000
		4500	3400	2200	1100
	2	3600	2600	1600	600
		4000	3000	1800	800
	3	3200	2200	1200	400
		3800	2600	1400	600
	4	3000	2200	1000	200
		3500	2400	1200	400

ML C
ML D

PNC 2: Cedar-Hemlock-Douglas-fir Forest
Owner – 4
State – OR

		Productivity Class			
		1	2	3	4
Condition Class	1	2000	1700	1500	1500
		4500	3500	2500	
	2	500	500	500	400
		3500	3000	1500	
	3	100	100	100	50
		100	100	100	
	4	100	100	100	100
		100	100	100	

ML A5
ML D5

PNC 5: Mixed Conifer Forest
Owner – 4
State – CA

		Productivity Class			
		1	2	3	4
Condition Class	1	6000	4500	2000	3000
	2	5000	3800	1700	2500
	3	1000	900	700	1300
	4	400	400	600	1000

ML B

FORESTED SITES

PNC 10: Western Ponderosa Forst
Owner – 4
State – OR

		Productivity Class			
		1	2	3	4
Condition Class	1	800 900	800 900	800 900	800 900
	2	100 100	100 100	100 100	100 100
	3	200 500	200 500	200 500	200 500
	4	400 600	400 600	400 600	400 600

ML B3
ML D4

PNC 11: Douglas-fir Forest
Owner – 1
State – MT

		Productivity Class			
		1	2	3	4
Condition Class	1	4000	4000	1700	500
	2	2000	2000	900	300
	3	1000	1000	500	200
	4	700	700	500	100

ML B2, B3

PNC 14: Western Spruce-Fir Forest
Owner – 1
State – CO

		Productivity Class			
		1	2	3	4
Condition Class	1	4200 4000	3000 3200	2200 2200	1200 1200
	2	3000 3000	1500 2000	1000 1600	500 1000
	3	1000 1600	400 1000	300 800	100 300
	4	0 500	0 100	0 100	0 100

ML B3
ML C5

PNC 21: Pinyon-Juniper
Owner – 1
State – AZ

		Productivity Class			
		1	2	3	4
Condition Class	1	900 1200	700 1000	500 700	200 300
	2	800 1100	600 900	400 600	200 200
	3	700 1000	500 800	300 500	100 200
	4	600 800	400 700	200 400	100 100

ML B1
ML D1

PNC 26: California Oakwoods Forest
Owner – 4
State – CA

		Productivity Class			
		1	2	3	4
Condition Class	1	2900 4200	2900 4200	2900 4200	2900 4200
	2	3200 4500	3200 4500	3200 4500	3200 4500
	3	3000 3600	3000 3600	3000 3600	3000 3600
	4	2900 3500	2900 3500	2900 3500	2900 3500

ML B1
ML D1

PNC 91: Oak-Hickory Forest
Owner – 4
State – MD

		Productivity Class			
		1	2	3	4
Condition Class	1	800 400	800 400	1000 1500	1200 1500
	2	300 4000	300 4000	400 2000	600 1500
	3	2000 4000	2000 4000	500 2000	700 1500
	4	300 4000	300 4000	300 2000	300 1500

ML A1, A3
ML D3

PNC 95: Appalachian Oak Forest
Owner – 4
State – PA

		Productivity Class			
		1	2	3	4
Condition Class	1	800	800	700	600
	2	600	600	600	500
	3	500	500	500	500
	4	500	500	500	600

ML C2

PNC 101: Oak-Hickory-Pine Forest
Owner – 4
State – VA

		Productivity Class			
		1	2	3	4
Condition Class	1	1200	1200	1000	1000
	2	1000	1000	400	200
	3	600	700	500	600
	4	500	400	500	600

ML B3

PNC 102: Southern Mixed Forest
Owner – 4
State – FL

		Productivity Class			
		1	2	3	4
Condition Class	1	3000 750	2000 500	2000 500	1000
	2	2200 2200	1500 1500	1500 1500	800
	3	1200 1200	800 800	800 800	400
	4	1200 1500	800 1000	800 1000	400

ML A3
ML A6

PNC 103: Southern Floodplain Forest
Owner – 4
State – LA

		Productivity Class			
		1	2	3	4
Condition Class	1	1000 12000	1000 12000	800	300
	2	900 12000	900 12000	700	200
	3	200 12000	200 12000	200	100
	4	300 12000	300 12000	200	100

ML A2
ML E

APPENDIX 2

Dominant Climax Species Present in SCS Range Site Descriptions

Graminoids

Agro.	*Agropyron* spp.[1]
Agsm	*A. Smithii*
Agsp	*A. spicatum*
Agtr	*A. trachycaulum*
Andro.	*Andropogon* spp.
Anba	*A. barbinodis*
Ange	*A. gerardi*
Anha	*A. hallii*
Anli	*A. littoralis*
Ansc	*A. scoparius*
Avfa	*Avena fatua*
Bocu	*Bouteloua curtipendula*
Boer	*B. eriopoda*
Bugr	*B. gracilis*
Bohi	*B. hirsuta*
Brca	*Bromus carinatus*
Brmo	*B. mollis*
Brri	*B. rigidus*
Buda	*Buchloe dactyloides*
Caru	*Calamagrostis rubescens*
Calo	*Calamovilfa longifolia*
Carex	*Carex* spp.
Cafi	*C. folifolia*
Cage	*C. geyeri*
Cane	*C. nebraskensis*
Deca	*Deschampsia caespitosa*
Dist	*Distichlis stricta*
Elci	*Elymus cinereus*
Erin	*Eragrostis intermedia*
Feid	*Festuca idahoensis*
Feme	*F. megalura*
Fesc	*F. scabrella*
Hija	*Hilaria jamesii*
Himu	*H. mutica*
Junc.	*Juncus* spp.
Ledu	*Leptochloa dubia*
Muem	*Muhlenbergia emersleyi*
Mupo	*M. porteri*
Orhy	*Oryzopsis hymenoides*
Paob	*Panicum obtusum*
Pavi	*P. virgatum*
Pasp.	*Paspalum* spp.
Poa	*Poa* spp.
Pofe	*P. fendleriana*
Poju	*P. juncifolia*
Pone	*P. nevadensis*
Pose	*P. secunda*
Puai	*Puccinellia airoides*
Scbr	*Scleropogon brevifolius*
Sema	*Setaria macrostachya*
Sihy	*Sitanion hystrix*
Sonu	*Sorghastrum nutans*
Sppe	*Spartina pectinata*
Sporo.	*Sporobolus* spp.
Spai	*S. airoides*
Spas	*S. asper*
Spcr	*S. cryptandrus*
Spgi	*S. giganteus*
Spwr	*S. wrightii*
Stco	*Stipa comata*
Stth	*S. thurberiana*
Stvi	*S. viridula*
Trich.	*Trichloris* spp.

Forbs

Basa	*Balsamorhiza sagittata*
Erci	*Erodium cicutarium*
Eriog.	*Eriogonum* spp.
Lup.	*Lupinus* spp.
Opunt.	*Opuntia* spp.
Tri.	*Trifolium* spp.

Shrubs

Acacia	*Acacia* spp.
Agave	*Agave* spp.
Ararn	*Artemisia arbuscula* var. *nova*
Arfi	*A. filifolia*
Arri	*A. rigida*
Artr	*A. tridentata*
Artrv	*A. tridentata* ssp. *vaseyana*
Artrw	*A. tridentata* ssp. *wyomingensis*
Atca	*Atriplex canescens*
Atco	*A. confertifolia*
Atga	*A. gardneri*
Cepa	*Celtis pallida*
Coleo.	*Coleogyne* spp.
Eula	*Eurotia lanata*
Flce	*Flourensia cernua*
Krame.	*Krameria* spp.
Latr	*Larrea tridentata*
Pofr	*Potentilla fruticosa*
Rhtr	*Rhus trilobata*
Rosa	*Rosa* spp.
Save	*Sarcobatus vermiculatus*
Shar	*Shepherdia argentea*
Syal	*Symphoricarpos albus*
Syor	*S. oreophilus*
Yucca	*Yucca* spp.
Yuba	*Y. baccata*

Trees

Cepa	*Celtis pallida*
Jumo	*Juniperus monosperma*
Juos	*J. osteosperma*
Jusc	*J. scopulorum*
P–J	*Pinus edulis – Juniperus* spp.
Pied	*P. edulis*
Pipo	*P. ponderosa*
Prju	*Prosopis juliflora*
Prun.	*Prunus* spp.
Quer.	*Quercus* spp.
Qudo	*Q. douglasii*
Qulo	*Q. lobata*
Quma	*Q. marilandica*
Qust	*Q. stellata*
Quvi	*Q. virginiana*

[1] *The term "spp." designates that either multiple species of the same species of the same genera are present, or the species is unknown.*

Mitchell, John E., and James B. Pickens. An evaluation of herbage and browse production estimators used in the 1980 RPA assessment. USDA Forest Service Research Paper RM–259, 32 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Interdisciplinary team estimates of herbage/browse production used in the 1980 RPA Assessment were evaluated using three approaches. Estimates for nontimbered areas were mostly accurate; however, intrinsic relationships between forage production and productivity/condition classes were inconsistent. Production estimates for forested areas were more difficult to intrepret, in part because of insufficient independent data. Intrinsic relationships were also inconsistent.

Keywords: herbage/browse/forage production, RPA Assessment, interdisciplinary teams, intuitive models, range sites

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Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526